THE TREATMENT OF FRACTURES

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VOLUME III

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The following injuries may occur in the region of the knee joint

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2 Fractures of fibula, tibia or its condyles
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 b) Fracture of the patella
 c) Rupture of the patellar ligament
 d) Avulsion of the tibial tuberosity
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5 Dislocation of the knee joint
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 a) Sprain
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Movements of the Normal Knee Joint

Movements of the joints during walking occur in the sagittal plane and, in addition, flexion and extension are always associated with rotation The degree of this rotation differs in different individuals and produces a typical gait This movement of rotation is lacking in artificial limbs, and persons walking with prostheses can immediately be recognized by their gait

All movements which are not mere jerks can be carried out smoothly and powerfully only when associated with rotation For example, a nail can be driven into a wall by a blow with a hammer But it cannot be pulled out unless rotation is associated with traction

Every movement of flexion and extension of the knee joint is associated with rotation of the tibia on the femur, or of the femur on the tibia if the latter is fixed If the knee is flexed without resistance, the tibia rotates outward On extension it rotates inward until an angle of 175° is reached The anterior cruciate ligament is then at its maximum tension, and complete extension can only be carried out if the tibia now rotates outwards This is the so called locking movement

If the tibia is fixed the femur rotates in the opposite direction, on flexion it rotates inwards and on extension up to 175° it rotates outwards and in the last 5° it again rotates inwards

Many muscles act not only on the joints over which they pass, but also on those at a distance, the quadratus plantae, for example, not only raises the arch of the foot but, if the foot is fixed, acts also as an external rotator of the hip joint When it contracts, raising the arch of the foot, outward rotation of the talus is produced As the talus lies firmly in the socket of the malleoli, the tibia, the extended knee joint, and the femur are externally rotated at the hip Conversely, on outward rotation of the hip, with the leg fixed, the arch of the foot is raised One can easily test this on one s own leg

In going downstairs, the leg bears the weight with hip and knee extended, and ankle bent at right angles, and then all three joints are flexed The femur rotates outwards during the first 5° of flexion and then rotates inwards In outward rotation of the femur between 180° and 175°, giving way of the leg at the hip and knee joints is prevented by the contraction of the vastus lateralis In inward rotation of the femur, which accompanies flexion from 175° to 40°, giving way is prevented by the contraction of the gracilis, semitendinosus, sartorius, the vastus medialis, and the outward rotators of the hip joint In walking downstairs these muscles have to hold the weight of the body and stretch at the same time

Examination of the Knee Joint with Injuries Which Make Walking and Standing Impossible

For exact examination of an injured knee it is essential to have clothing removed from *both* legs In severe injuries the patient can only be examined in a recumbent position, in slight injuries he may be examined also while walking, standing and sitting While the patient walks or stands, his legs are inspected from in front, from behind, and from both sides and compared with each other The examination of the sitting patient is carried out in such a way that the patient sits on the edge of a chair with both knees extended as far as possible, and with the heels resting on the floor Then flexion, rotation, etc, are tested

Previous History First the patient s name, age, occupation, and address are recorded, then his height and body weight Next he is asked how the accident occurred and whether the injury was produced by a great or a small force Fractures or ruptures of ligaments may follow a fall from a height, being run over, being buried by collapsing material, or being hit by heavy objects Ruptures of the collateral ligaments, mainly the medial one, often follow a fall in skiing, or a kick against the knee especially in soccer Strains of the ligaments and tears of the menisci may occur when a person slips or twists his leg The patient then often feels and hears a crack in the joint There is always severe pain With fractures and dislocations weight bearing and walking are, as a rule, no longer possible With sprains and ruptures of the ligaments walking is impaired

Inspection One determines whether the patient is pale or in shock, and whether he complains of pain With the patient still fully clothed one sees whether the leg is rotated, angulated, flexed, or extended Angulation of the leg occurs only in fractures dislocations, or complete ruptures of a collateral ligament with severance of the cruciate ligaments Then the patient s clothes

Inward and outward rotation is determined by the shape of the condyles of the femur. The lateral femoral condyle courses approximately in a sagittal plane, while the course of the medial femoral condyle is sharply curved with the convexity of the curve to the medial side. In flexion and extension the tibia rotates around a longitudinal axis passing near the medial side of the lateral tibial condyle. For this reason the lateral meniscus travels through a greater arc. If the tibia is fixed the femur rotates on the tibia.

Inward rotation of the bent knee is activated by the pes anserinus (sartorius, gracilis and semitendinosus), the semimembranosus, and the popliteus, external rotation by the biceps and the tensor fasciae latae. According to most anatomists there are no inward or outward rotators on the extensor aspect. However when we examine the vastus medialis arising on the posterior surface of the femur from the inner lip of the linea aspera and the fibers of its lower portion running almost transversely to its insertion on the rectus tendon and the patella, it is at once apparent that this muscle is not only an extensor, but also an inward rotator of the tibia, or if the tibia is fixed, an outward rotator of the femur. I have previously demonstrated that this muscle on account of its transverse fibers will also act as an adductor of the entire extensor mechanism of the knee[1]. The vastus lateralis and tensor fasciae latae are strong outward rotators of the tibia and if the latter is fixed, inward rotators of the femur.

In climbing stairs the advanced leg at first bears no weight. It is bent at the hip and knee the ankle being in dorsiflexion. The bent leg then bears the entire weight, and straightens so that extension occurs simultaneously in all three joints. At the knee the tibia is rotated outwards and the femur inwards. Since the tibia is fixed, the knee is straightened in such a way that the femur rotates outwards on its axis during extension. This external rotation results first from the action of the vastus medialis and then of all muscles which rotate the femur outwards at the hip, primarily the gluteus maximus, which extends the hip and thus the knee, and then also the piriformis the obturator externus and internus, the quadratus femoris and the gemelli. In the last five degrees of extension inward rotation of the femur is produced by the action of the vastus lateralis and the increasing tension of the anterior cruciate ligament. Finally, by the action of the extensors of the ankle, gastrocnemius, soleus, tibialis posterior, flexor hallucis longus flexor digitorum longus, and peronei, the foot is brought into plantar flexion and the body is raised.

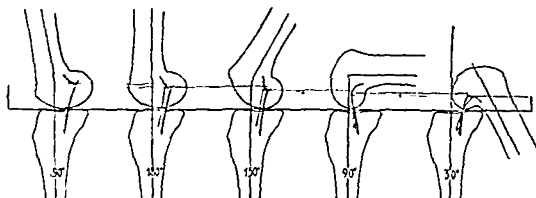
By the action of the calf muscles, which insert by way of the tendo Achillis into the heel bone, the latter is rotated into a position of supination and at the same time contraction of the tibialis posterior peroneus longus flexor hallucis longus, and flexor digitorum longus raises the arch of the foot and brings the fore-foot into pronation in relation to the heel. The quadratus plantae and the short flexors of the toes help to raise the arch of the foot. The action of the long and short flexors of the toes in raising the arch of the foot is enhanced because during plantar flexion at the ankle the toes are held firmly on the ground in dorsiflexion.

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[1] Böhler L Ztschr f orth Chir 38 303—310 623—628 1917

In a *suspected fracture* try to elicit pain on impingement by a light blow on the heel, examine for pain on rotation by slight torsion, and examine for pain on traction by longitudinal traction at the ankle joint Then grasp the thigh above the knee with one hand and the lower leg above the ankle with the other hand, and adduct and abduct the lower leg (figs 2167—2170) In intra-articular fractures of the femur or tibia abnormal motion will be found as well as a varus or valgus deformity, and often crepitation In dislocations of the knee there is abnormal shape and springy fixation

Examination of the Collateral Ligaments and Menisci Abduction The lateral side of the thigh above the knee is grasped with one hand, and the lower leg above the ankle with the other hand and the tibia abducted on the femur In sprains of the medial collateral ligament pain will be produced at



Sketched in April 1928

Fig 2171 —Overextending the knee joint to 190° causes overstretching of the collateral ligaments In full extension the lateral ligaments are normally tight In flexion to 150° the lateral ligaments are relaxed and therefore rotatory movements are possible In further flexion the lateral ligaments are still further relaxed

the medial side of the knee In complete ruptures of the medial collateral ligament a gaping of the medial joint space will be noted on abduction and the patient will feel slight pain medially at the site of rupture When the stress is released suddenly a hard knock is clearly felt and heard as the joint surfaces come together In injuries to the lateral meniscus the patient will feel pain at the lateral side of the knee joint on abduction (figs 2167, 2168) as the meniscus is being compressed between the joint surfaces

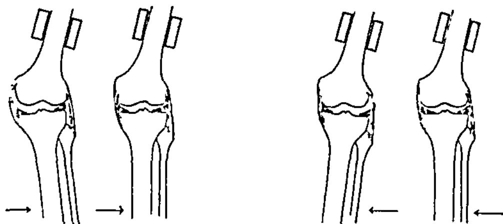
Adduction The medial side of the thigh above the knee is grasped with one hand, and the lateral side of the lower leg above the ankle with the other hand and the lower leg adducted with the knee completely extended In injuries of the lateral collateral ligament pain will be produced at the lateral side of the knee due to stretching of the injured ligament In a complete rupture of the lateral collateral ligament or avulsion of the tip of the fibula this maneuver will cause the joint space to gape laterally One must know that in flexion of 160° or more a normal knee will gape somewhat and a knee that can be hyperextended will be loose already at 180° In an injury to the medial meniscus pain will be felt at the medial side of the joint on adduction (figs 2169, 2170)

If in a sprain of the medial collateral ligament the attempt is made to hyperextend the knee joint fully, due to tension of the ligament pain will be

are removed so that both legs can be inspected *Protection from cooling must not be omitted*

Examination for Change of Color, Shape and Skin Temperature One determines whether the skin is pale or blue, whether it is normal or shows abrasions or extravasations of blood, whether the axis of the injured leg is angulated, and if so in which direction, whether bony prominences are visible, and whether the knee is extended or flexed, or swollen so that its contours become indistinct Changes of the skin temperature can be felt with the hand

Examination of Pulse and Reflexes After all findings of the general examination have been written down, the pulse on the dorsum of the foot and



2167 2168 Sketched in March 1928 2169 2170

Figs 2167 2168—Abducting the lower leg on the fixed femur produces pain on the medial side of the knee if the medial collateral ligament is sprained or torn and on the lateral side of the knee if the lateral meniscus is injured

Figs 2169 2170—Adducting the lower leg on the fixed femur produces pain on the lateral side of the knee if the lateral collateral ligament is sprained or torn and on the medial side if the medial meniscus is injured

behind the medial malleolus is taken for both feet Then the patellar reflex on the sound side is tested as well as the form and width of the pupils and their reactions to light and convergence

Examination of Motion The patient is asked to raise the extended leg This will be impossible in complete fractures of the femur or head of the tibia or in injuries of the extensor mechanism (rupture of the quadriceps fracture of the patella, rupture of the patellar ligament, or avulsion of the tibial tuberosity)

From the toes upwards to the hip active motion of all joints is examined first on the sound side and then on the injured side for comparison and also to see that the patient understood what he was asked to do The patient is asked to repeat these movements on both sides simultaneously In a case of limited motion the range of motion is measured in degrees and recorded, and for comparison the range of the sound side as well The normal range of motion of the knee joint is 180° to 40° In elderly people the uninjured knee can often be straightened to only 170° and flexed to only 60° or even less

Palpation Not until the these findings have been recorded does the examiner touch the patient

Pneumoarthrography Some loose bodies and injuries to the menisci can be recognized only after the joint has been filled with air or oxygen before X-rays are taken

Examination in Recent and Old Injuries of the Knee Joint in Patients Who Can Walk

Previous History After the patient s age, etc, has been recorded he is questioned about the time of the accident and how it happened, at what time the complaints started and how they were influenced by walking, especially uphill and downhill and walking on stairs The patient is asked whether he sometimes feels a protrusion or a locking in the knee and whether the knee gives

Differential Diagnosis in Injuries to the Knee Joint

Injuries to the Medial Meniscus	*Sprains of the Medial Collateral Ligament*	*Complete Tears of the Medial Collateral Ligament*	*Painful Knee in Heavy Women*
Indirect violence by rotation	Indirect violence by rotation and lateral angulation	Indirect violence by rotation and lateral angulation	Slow onset of complaint by disturbed statics
Sudden severe pain	Little pain initially increasing later on	Sudden severe pain	Pain develops very slowly
No swelling	No swelling	Swelling	Swelling in severe cases
No effusion	No effusion	Effusion of blood	Thickening of capsule without effusion
Limited extension only in a locked knee	Extension usually limited	Extension not limited	Gradually increasing limitation of extension
Pain medially on adduction	Pain medially on abduction	Pain medially on abduction	Indistinct symptoms on abduction and adduction
Pain on pressure *only* over joint space	Tenderness *only above* the joint space	Tenderness above or below the joint space	Tenderness over the whole medial side especially over pes anserinus and joint margins
Routine X ray negative	Routine X ray negative	Routine X ray negative	Routine X ray positive (arthrotic changes)
Pneumoarthrography positive in 80 to 90%	Pneumoarthrography negative	X ray in forced abduction positive with or without pneumoarthrography	—

elicited at its femoral insertion In a locked displaced torn meniscus, on the other hand, pain due to compression of the meniscus will be felt at the anterior side of the joint space

Examination of the Cruciate Ligaments Both knee joints are flexed to an angle of about 120° to 100° With one hand the lower leg is grasped above the ankle with the other hand below the popliteal space The head of the tibia can be displaced forwards on the femur in rupture of the anterior cruciate ligament, and backwards in the case of rupture of the posterior ligament One speaks of an anterior or posterior 'drawer sign (figs 2270, 2264 g—m)

Examination for Pain on Rotation With the knee flexed at 90°, the lower leg is grasped above the ankle with both hands and quickly and strongly rotated inwards and outwards In a tear of the medial meniscus there is usually pain at the medial side

Motion of the Patella Only after all these examinations is the knee joint itself touched With the knee extended the patella is grasped between thumb and index finger and moved laterally, upwards, and downwards For comparison motion of the sound patella is examined in the same way In a swollen knee we test whether the patella lies close to the femur or floats on an effusion of blood (ballottement) In a case of slight effusion the patella becomes ballottable only if manual pressure on the suprapatellar pouch drives the effusion into the knee joint

Examination for Crepitation The hand is placed on the anterior surface of the knee joint which is flexed and extended If the joint surfaces are rough and uneven from arthrotic changes grinding, grating or cracking is felt

Examination of Pain on Pressure With both knees flexed at right angles the joint space of the sound and then of the injured side is examined for tenderness by moving a palpating finger from the antero medial to the antero lateral side and then to the rear on both sides Then the patient is told to lift the fore foot and rotate the lower leg on the heel while the joint space is palpated In injuries to a meniscus one usually detects tenderness limited to the anterior portion of the joint space

Then the insertions of the collateral ligaments the course of the semitendinosus and the whole joint are tested for tenderness

Aspiration of the Joint In severe and painful effusion the fluid is withdrawn under local anesthesia and under the greatest aseptic precautions A slender needle is used for local anesthesia near the craniolateral edge of the patella The effusion is evacuated through a large needle One determines whether the joint is filled with serum blood or pus *Drops of fat* floating on the blood almost always indicate an injury to the bone

To determine the type and extent of the bony injury X-rays must be taken in two planes, namely exactly anteroposteriorly and exactly laterally These pictures show not only recent injuries to the bones and ligaments but also changes caused by previous accidents and disease If a gaping joint has been detected by clinical examination, stress films should be taken to demonstrate the degree of gaping of the joint space This examination should be carried out only within the first two days after the accident (figs 2266 2267)

Ruptures of the quadriceps tendon	13
Fractures of the patella	578
Ruptures of the patellar ligament	20
Avulsion of the tibial tuberosity	9
	620

RUPTURES OF THE QUADRICEPS TENDON AND THE PATELLAR LIGAMENT

Etiology. These injuries often occur following indirect violence, as in slipping on the ground or doubling up of the knee, rather than by a fall or a blow on the knee. A bone flake is sometimes pulled off the upper or lower pole of the patella together with the tendon or ligament. As a rule, rupture of the quadriceps tendon is associated with a wide rupture of the vasti medialis and lateralis, and rupture of the patellar ligament with severance of the lateral and medial parapatellar ligaments.

Age and Sex Distribution. We have observed rupture of the quadriceps tendon and ruptures of patellar ligament only in male patients. Patients with rupture of the quadriceps tendon usually were over 40 and obese. Most of our patients were either inn-keepers or clergymen. Patients with ruptures of the patellar ligament were younger.

Diagnosis. Following slipping on the ground the patient feels a sharp pain in his knee and it gives way when he attempts to walk. Within the first hour after the accident, a sulcus can be seen proximal or distal to the patella, and a finger can be laid into it. Active extension of the knee joint or lifting the extended leg is no longer possible. After one hour the knee becomes severely swollen and the sulcus can no longer be seen but can be palpated.

In ruptures proximal to the patella, the X-ray shows distal displacement and sometimes anterior tilting of the patella. In ruptures distal to the patella it is pulled proximally by the muscles.

Histological examination usually shows degenerative changes of the tendon similar to those in ruptures of the tendo Achillis.

Treatment. The repair of the extensor mechanism is carried out as in fractures of the patella (see p. 1527). At operation one will generally find that severance of the vastus medialis and lateralis or of the parapatellar ligaments is present.

FRACTURES OF THE PATELLA

General Remarks

Etiology. The patella is a sesamoid bone in the extensor tendon of the knee. It may be fractured by direct violence, i. e., by a fall or a blow on the knee, or more often by indirect violence, i. e. by sudden strong contraction of the quadriceps muscle in stumbling, and the patella is broken over the lower end of the femur of the bent knee. If the extensor mechanism is torn across, the bone fragments then become separated. Direct and indirect violence often act simultaneously.

way In most injuries and diseases of the knee, walking downhill is more troublesome than walking uphill

Inspection Before the patient removes his clothing he should be told to walk up and down the room a few times It will then be seen whether he needs a cane or can walk without it, whether he limps moves his knee in walking or holds it stiff in extension or flexion Then both legs should always be bared completely and flexion of the injured knee measured Then the patient is again asked to walk and to stand still, so that color, shape mobility and muscle action can be observed from in front from behind and from both sides Then deep knee bending and standing on one leg are carried out

Then pulse and reflexes are examined as described on p 1508

Testing the Integrity of the Ligaments in the Standing Patient With the patient bearing the greater part of his body weight on the sound leg, the injured knee is grasped with both hands and moved medially, laterally, posteriorly and anteriorly With loose collateral or cruciate ligaments one can distinctly feel the condyles knocking against each other As a rule this sign is more pronounced under these conditions than in a leg bearing no weight

For further examination the patient should be seated on the anterior edge of the chair, he should extend his legs as far as possible with his heels resting on the ground One observes the color of the skin, whether the contours of the joint are clear-cut or indistinct, whether the joint can be fully extended, and whether the muscles are atrophic on one side

Motion The patient is asked to lift first the sound leg then the injured leg with the knee extended The motion of the toes and ankle joints is tested To evaluate flexion of the knee the patient is requested to bring his knee up to the chest and to press his heel towards the buttock, with the ipsilateral hand If the heel cannot be brought to touch the buttock, the gap is measured in centimeters The flexion angle of the knee is measured in degrees

Palpation The examination regarding the collateral and cruciate ligaments, pain on rotation, motion of the patella, crepitation and pain on pressure the aspiration of the joint and the X rays are carried out as in the examination of the recumbent patient (see pp 1509 and 1510)

Measurement of the Circumference If one leg is atrophic, the circumference of both legs is measured at the level of the patella 10 cm cranial to it and at the same level of the calves

76 INJURIES OF THE EXTENSOR MECHANISM OF THE KNEE

The extensor mechanism can rupture at four places, i e, in the region of the quadriceps proximal to the patella through the patella, distal to the patella in the region of the patellar ligament, or at the tibial tuberosity (avulsion) Schonbauer [1] has reviewed our injuries of the extensor mechanism He observed

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[1] Schonbauer Gedeckte Risse großer Sehnen am Bein Verhandlungen des 18 Kongresses der Deutschen Gesellschaft f Unfallheilk 1954

Application of the Plaster Cylinder for the Knee Joint

The following will be required

1 A table (fig 2175) for the patient to lie on
2 A small instrument table for support of the foot (fig 2175)
3 A second small instrument table on which to put flannel strips, sterile cotton-applicators, mastisol, and plaster cutters
4 A roll of cellulose or foam rubber (see Vol II/p 1215) for the heel (fig 2175)
5 A flannel strip, 30×5 cm (fig 2175)
6 A flannel strip, 70×5 cm (fig 2175)

Both flannel strips are incised, the cuts being 5 cm apart and 1—1 5 cm deep so that the edge can be turned over later on

7 Mastisol
8 Cotton applicators (Vol I/fig 152)
9 Plaster cutters
10 Six to eight 17 thread plaster bandages, 15 cm × 5 m, weighing 400 Gm
11 Stool on which to rest the sound leg

After drying of the Unna's paste the patient is so placed on the table that the injured limb lies with his hips extending beyond the edge of the table The heel is laid over a roll of cellulose or foam rubber on the small instrument table The sound leg with the knee flexed to a right angle rests on a stool A helper supports the knee with one hand to prevent overextension and with the other hand he holds the fore-foot The 30×5 cm flannel strip is wound round the lower leg four finger-breadths above the ankle and glued with mastisol Then the upper end of the thigh is dabbed with a few strokes of mastisol, and the 70×5 cm flannel strip is applied in such a way that both ends cross laterally Folds should be avoided A plaster slab from 60 to 80 cm long is made from two bandages and applied to the dorsal side of the thigh and lower leg from hip to ankle in such a way that it does not reach beyond the flannel strips Two circular plaster bandages are wound over it After applying the second plaster bandage another plaster splint 75 cm long is made, divided into three equal parts, and placed on the inner, outer, and anterior aspects of the knee The incised edges of both flannel strips are turned back, and one to three more circular plaster bandages are applied according to the size of the leg

The *inscription* of the cast is carried out as described in Vol II/p 1172

Period of Immobilization The plaster cylinder is removed five weeks after the injury

Exercises The patient can walk with this plaster cast as soon as it is dry In the first week he should walk at least 1 Km daily, increasing this by 1 Km each week, *if this causes no pain* In addition he should practice raising the leg to the horizontal position several times a day while standing to strengthen the thigh muscles and to exercise the whole body

Further Treatment After removal of the plaster cylinder an Unna's paste dressing is applied from the web of the toes up to the knee (see p 1514), and an elastic bandage is worn round the knee during the day and removed at night

Site of Fracture Most frequently the fracture occurs in the middle portion (figs 2188, 2191), but it also occurs in the lower third (figs 2184, 2196—2201), *and occasionally in the upper third*

Types of Fracture As a rule, direct violence leads to stellate comminuted fractures (figs 2178, 2215) and indirect violence to simple transverse fractures Approximately 80% are transverse fractures, 12% longitudinal fractures, and 8% stellate and comminuted fractures

Diagnosis If the extensor mechanism is torn and the fragments are separated, diagnosis is simple At first a deep sulcus is visible, in the middle of the patella, which will disappear after 2—3 hours when the joint becomes filled with blood A finger can be laid between the fragments Active extension of the knee joint or lifting the extended leg off the underlying support is no longer possible, there is loss of active extension, whereas passive extension is not impeded

If the fragments are not separated, a sign that the extensor mechanism is intact, the extended leg can usually be actively lifted though with some difficulty Aspiration of the joint will always yield blood with drops of fat

Complications After Fractures of the Patella If fractures of the patella with separation of the fragments are not treated properly, e g, by reduction by immobilization and exercises, non-union will result making active extension of the knee impossible Such knees will buckle in walking and are no longer fit for heavy work Arthrotic changes will develop, especially after comminuted fractures, if step like displacements or uneven joint surfaces have remained Delayed operation or energetic aftertreatment with massage passive motion and excessive heat may lead to impaired motion

Avoidance of Complications After Fractures of the Patella Complications can be avoided if all fragments are accurately brought in apposition, if the extensor mechanism is sutured, if immobilization is continued long enough, if active exercises are performed and if exaggerated aftertreatment with passive stretching and excessive heat is avoided

Treatment of Closed Fractures of the Patella Without Separation of the Fragments

If the fragments are apposed or separated by only 2—3 mm, the extensor mechanism has not been torn These patients can be put into a plaster cylinder as early as 4—5 days after the accident if the swelling of the joint has subsided At first an *Unna's paste dressing* is applied from the web of the toes to the middle of the lower leg (see Bohler [1])

[1] Bohler Verbandlehre fur Schwestern Helfer Studenten und Ärzte German edition pp 74—86 Vienna Maudrich 1947
— Sargı bilgisi Turkish edition pp 74—86 Ankara Milli Egitim Basinevi 1949
— 1950 Verbandleer Dutch edition pp 84—95 Amsterdam Scheltema and Holkema
— 1950 Manuel de ataduras Portuguese edition pp 94—107 Sao Paulo Melhoramentos
— 1951 Chinese edition pp 61—71 Shanghai
— 1951 Nauka o zavojima Yugoslavian edition pp 81—92 Belgrade Medicinska Knjiga
— 1952 Manuale del bendaggio Italian edition pp 71—80 Milan Vallardi

Questions We Should Ask Ourselves in Order to Avoid Failures When Applying a Plaster Cylinder for the Knee Joint

1 Have I prepared the equipment described on p 1515 and checked it for completeness and quality?
2 Have I applied an Unna's paste dressing from the web of the toes to the middle of the lower leg?



2178, February 10, 1928 2179, February 17 1928 2180 May 11 1928

Fig 2178—Star shaped comminuted fracture of the patella with marked displacement of the fragments on the joint surface No significant distraction evidence that the extensor mechanism has not been torn

Fig 2179—Check X ray re fig 2178 afer removal of bloody effusion and pressing the fragments against the articular surface of the femur The fragments have been well apposed on deep surface One week after the accident when the swelling had subsided an Unna s paste dressing and plaster cylinder were applied for five more weeks

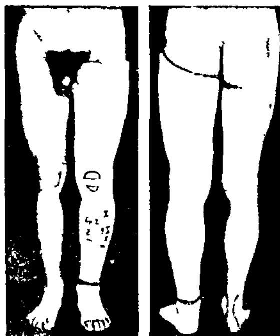
Fig 2180—Check X ray re figs 2178 2179 three months later Bone soundly united with complete restoration of motion to the knee joint

3 Have I dabbed the skin with mastisol and applied the incised 30×5 cm flannel strip 3—4 finger-breadths above the ankle joint?
4 Have I dabbed the skin with mastisol and applied the incised 70×5 cm flannel strip to the upper end of the thigh without folds in such a way that the ends cross laterally?
5 Has the knee been supported by a helper so that it does not sink into hyperextension?
6 Have I applied the dorsal plaster slab in such a way that it does not extend beyond the flannel strips and cut into the skin?
7 Have I turned back the flannel strips before applying the last plaster bandage so that the edges of the cast become smooth and do not press against the skin?



February 8 1932

FIG 2175—Positioning for application of a plaster cylinder for the knee The patient s body and hips lie on a table The injured leg rests on a second table An Unna s paste dressing is applied from the web of the toes to the knee A roll of cellulose or foam rubber under the tendo Achillis takes pressure off the heel The sound leg with the knee bent at a right angle is supported on a stool A strip of flannel is applied round the leg four finger breadths above the ankle The 70×5 cm strip of flannel is applied round the most proximal part of the thigh in such a way that the ends cross laterally



2176 January 28 1931 2177

FIGS 2176 2177—Complete plaster cylinder for fracture of the patella seen from in front and behind Unna s paste on foot Strip of felt above ankle The cast extends laterally up to the tip of the greater trochanter On the cast are marked the outline of the fracture before reduction the dates of accident operation application of plaster and of removal and the name of the doctor These latter are marked on the lower leg so that they can be read without removing the trousers

Exercises on the knee flexion apparatus are also carried out (Vol II/figs 1574 1575) Full range of motion at the knee will be regained 3—6 weeks after removal of the plaster cylinder depending on the patient s age

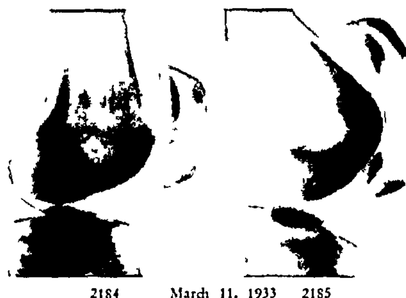


Fig 2184—Transverse fracture of the patella with little separation of the fragments on extension of the knee

Fig 2185—Check X ray re fig 2184 with the knee in flexion Wide separation of fragments a sign that the extensor mechanism has been severely torn Such cases can only be reunited by operation

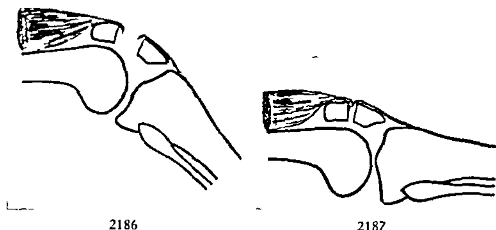


Fig 2186—The torn layers of tendon and periosteum overlap the fractured surfaces of the fragments which have been distracted

Fig 2187—If the knee is extended the fragments cannot be completely approximated because of the interposed tendinous aponeurosis If this is not removed non union will result

The Bipartite Patella (Patella Bipartita)

A frequent congenital anomaly of the patella is the separation of the upper lateral quadrant of the patella (fig 2182) This condition is difficult to recognize in the lateral picture (fig 2181), but can be easily seen in the tangential (fig 2183) and the anterior X-rays Congenital longitudinal separation of the patella parallel with its lateral or medial margins is rare It differs from recent longitudinal fractures in the rounded edges of the two surfaces, whereas in recent fractures the edges are sharp (figs 2183 a—d) Non-union following a longitudinal fracture may have to be considered An X-ray taken after a trivial injury to the knee joint showing signs of a patella bipartita has often



2181—2183 August 23 1935

Figs 2181—2183 —Bipartite patella (patella bipartita) Seen from the side from in front and tangentially from above The lateral picture shows the separation of the cranial part In the anterior picture the craniolateral portion is separated from the patella by a wide gap Fractures of the patella do not assume this shape The tangential view taken with the knee bent shows the separated portion clearly



2183 a



2183 b



2183 c

February 13 1945



2183 d
February 13 1945



2183 e
June 8 1954

Fig 2183 a —Longitudinal fracture through the lateral third of the left patella with wide separation sustained by a 20 year old apprentice who was knocked down by bomb blast and then buried by collapsing walls He could lift the extended leg Five days later the effusion of blood was aspirated 40 ml of blood were withdrawn Seven weeks later he was again fit for work and had no complaints Full range of active motion

Fig 2183 b —Lateral view re fig 2183 a Slight dorsal displacement of the lateral fragment

Fig 2183 c —Lateral view re fig 2183 a in slight rotation The fragment projects into the patellar groove

Fig 2183 d —Tangential X ray re fig 2183 a b The lateral fragment is displaced laterally and dorsally The fracture surface are clearly outlined evidence of a recent injury

Fig 2183 e —Check X ray re fig 2183 d nine and a half years later Established non union The lateral fragment has increased in size and has been displaced more laterally The fracture surfaces are rounded Normal range of motion no crepitation No complaints

8 Have I made the plaster cylinder too short? It should reach from the ankle up to the hip joint (figs 2176 2177)

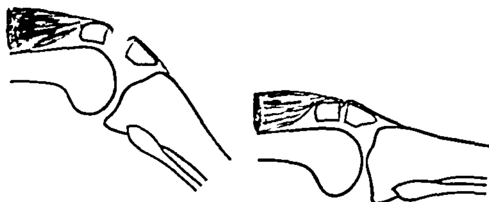
9 Have I *inscribed the plaster cast properly*?



2184 March 11 1933 2185

Fig 2184—Transverse fracture of the patella with little separation of the fragments on extension of the knee

Fig 2185—Check X ray re fig 2184 with the knee in flexion Wide separation of fragments a sign that the extensor mechanism has been severely torn Such cases can only be reunited by operation



2186 2187

Fig 2186—The torn layers of tendon and periosteum overlap the fractured surfaces of the fragments which have been distracted

Fig 2187—If the knee is extended the fragments cannot be completely approximated because of the interposed tendinous aponeurosis If this is not removed non union will result

The Bipartite Patella (Patella Bipartita)

A frequent congenital anomaly of the patella is the separation of the upper lateral quadrant of the patella (fig 2182) This condition is difficult to recognize in the lateral picture (fig 2181), but can be easily seen in the tangential (fig 2183) and the anterior X-rays Congenital longitudinal separation of the patella parallel with its lateral or medial margins is rare It differs from recent longitudinal fractures in the rounded edges of the two surfaces, whereas in recent fractures the edges are sharp (figs 2183 a—d) Non-union following a longitudinal fracture may have to be considered An X-ray taken after a trivial injury to the knee joint showing signs of a patella bipartita has often

been misinterpreted as a fracture of the patella and has been treated as such by immobilization In fractures of the patella with a small gap between the fragments the gap disappears within a few weeks or months, whereas longitudinal non-union develops if the fragments are separated widely (fig 2183 e) The gap of a congenital bipartite patella, however, remains equally wide Some erroneously call this a non union We have seen patients who for months were given so called callus-stimulating remedies like calcium, thymus tablets and X-ray therapy Since the gap did not disappear in spite of this, high disability pensions were paid although there was no functional disturbance

Such incorrect diagnosis, incorrect treatment, and incorrect disability evaluations cannot occur if one knows of the existence of the bipartite patella, and of its usual location in the upper lateral quadrant Patellar fractures of this shape do not occur

In recent injuries of the knee joint associated with an effusion of blood there will be drops of fat floating on the aspirated blood if the patella has been fractured They will be absent in a case of bipartite patella, unless another bone injury has occurred simultaneously

Conservative Treatment of Star-Shaped Fractures of the Patella and of Fractures with Little Separation of the Fragments

The important question in all fractures of the patella is whether or not the extensor mechanism has been torn The wider the gap between the fragments the more extensive the tear of the extensor mechanism Direct violence, e g, a fall on the patella may lead to comminution of the patella without tearing the extensor mechanism If the patella is exposed in such cases one will see that the extensor tendon passing over the patella is intact These fractures may also be treated conservatively

Application of a Compression Bandage On the first day light compression is exerted by means of foam rubber and elastic bandages To avoid congestion and pain they must not be pulled too tight If pain sets in the bandages are loosened

Aspiration of the Knee Joint and Reduction of the Fragments On the second or third day the knee joint is aspirated under local anesthesia After evacuation of the blood effusion the fragments are pressed against the femur with the knee extended Severe displacements can often be corrected in this way (figs 2170—2180 2210—2212) if not the fragments should be excised and the extensor mechanism sutured (figs 2207—2209) If reduction has been successful, another compression bandage is applied and the leg elevated on an oblique splint with the hip slightly flexed and the knee fully extended

Application of Unna's Paste and a Plaster Cylinder If within a few days the swelling and effusion in the joint have disappeared an Unna's paste dressing is applied from the web of the toes to the knee, and over it a plaster cast from ankle to hip as described on pages 1514—1516 The cast is removed five weeks after the injury

Inscription of the cast exercises and further treatment are carried out as described on page 1515

Radiological Determination [illegible] of T[illegible] the Extensor Mechanism If in th[illegible] late[illegible] [illegible] ceded (fig 2184) the gap between the fragments of th[illegible] small another X ray should be taken with the knee [illegible] In exter[illegible] of the extensor mechanism the fragments will b[illegible] parated as [illegible] ure 2185 This is an indication for operative treatment [illegible] suture of th[illegible] extensor mechanism with o[illegible] without excision of the patell[illegible]

Operative Treatment of Closed Fractures of the Patella with Wide Separation of th[illegible] Fragments

When the fragments are widely [illegible]parated i e when the extensor mechanism of the knee joint is torn full function can only, as a rule, be restored by suture

Some statistics show that the results of fractures which have not been operated upon are better than those which have been operated upon They do not, however, state which type of fracture was included If the unoperated cases were those without displacement i e less severe, the better results are easy to understand

History All formerly used methods are unsatisfactory, and only of historical interest Former writers had the idea that the "bone juice" (bone-marrow) got into the joint and caused it to become stiff To prevent this they advised that the patient should lie on his stomach during treatment Countless proposals have been made for bringing the separated fragments into close contact and for holding them until bony union occurs The simplest of these consisted in relaxing the quadriceps muscle by placing the leg on a splint with the knee extended and the hip flexed In spite of this the fragments remained separated, and new appliances were devised for grasping the two fragments from above and below with loops of leather or metal and trying to bring them together with bandages, screws, and springs But either the traction was too weak, or if it was stronger, it caused ulceration of the skin Malgaigne devised a clamp which grasped both upper and lower fragments by means of two sharp hooks, which pierced the skin, the two pairs of hooks were approximated by means of a screw The use of this was soon abandoned because it often caused infection of the knee joint with resulting amputations and deaths The same danger was incurred by the methods of Bruns and Olliver, in which traction was exerted on metal pegs and screws that were introduced into the fragments Volkmann carried out a subcutaneous tendon suture, Kocher used a subcutaneous wire round the fragments, through the joint, and fastened it in front over a piece of iodoform gauze None of these methods of treatment usually led to the desired result, namely, bony union of the fragments, because the torn fragments of aponeurosis which lay between the bones were not surgically exposed and removed (figs 2186 2187) and therefore the separated fragments did not become sufficiently approximated, and especially because the lateral tears of the extensor mechanism were not repaired

Lister in 1877, with the safeguard of antisepsis, was the first to open the joint widely and to suture the patella with wire Trendelenburg used the same method shortly afterwards But in spite of wiring the patella sometimes broke again, because either the wire tore or it cut through the spongy bone It was then

recognized that suture of the capsule and of the whole of the extensor mechanism was necessary If it is realized that the patella is only a sesamoid bone of the extensor tendon it is easy to understand how a thin wire around the patella is insufficient to support the weight of the body, even in simple walking, much less in jumping, if the extensor mechanism itself is not repaired

Requirements of the Operation When the fragments are separated, treat ment can only succeed if the bones and the torn extensor mechanism are freely



2188 December 22 1927 2189 December 31 1927 2190 April 5 1928

Fig 2188—Transverse fracture of the patella with separation of 3 2 cm at the back and 5 5 cm in front The fragments are angulated 90° to each other

Fig 2189—Check X ray re fig 2188 after suture of the extensor mechanism and bone

Fig 2190—Check X ray re fig 2189 twelve weeks later The fragments have united by bone but there is angulation probably silk suture having been laid too deep and to the fact that movements were allowed as early as after three weeks because the silk suture was placed too far dorsally and movements were already begun after three weeks

exposed all the soft par s removed from between the fragments the fragments accurately apposed or removed and the extensor mechanism united by suture

Since this necessitates opening the largest joint in the body and the one most susceptible to infection the most painstaking aseptic precautions must be taken The operation should only be undertaken by those who have mastered the technique, and it should only be done in a proper operating theater

Time of Operation The operation may be carried out in the first few hours as long as the hematoma has not yet penetrated in the surrounding tissue

or else after one week, when the hematoma has again been absorbed and the skin is normal We have abandoned early operation because some failures followed inadequate operations by inexperienced surgeons

Early Treatment After the first examination and after X-rays have been taken the leg is placed on a well padded Braun splint for one week The fore foot is suspended with Unna's paste traction (see Vol II/p 1196) or a triangular bandage (fig 2641) If there is painful distention of the joint, the effusion of blood may be aspirated This, however, is rarely necessary Sometimes we apply a compression bandage with rubber sponges



2191 2192 2193 2194 2195
Nov 21 1934 Dec 28 1934 Oct 29 1936 October 29 1936

Fig 2191 —Transverse fracture of the patella sustained by a 77 year old gate keeper who slipped on even ground and fell on his knee Operation on the 10th day Unna s paste and plaster cylinder on the 22nd day 38 days after the operation the plaster cylinder was removed

Fig 2192 —Check X ray re fig 2191 after removal of the plaster cylinder 38 days after the operation The fragments are well apposed especially at the articular surface Anteriorly the fracture line can still be seen Considerable decalcification

Fig 2193 —Check X ray re figs 2191, 2192 two years later Normal shape and normal density of patella At the site of the former fracture there is slight density of the bone structure

Fig 2194 2195 —Photographs of fig 2191 The patient who is now 79 years of age resumed his old job 14 weeks after the injury He can walk well over stairs Knee motion 180° to 75° as against 180° to 55° on the sound side With the hip flexed he extends his knee in the photograph only to 170° Strong muscles No complaints

Exercises in the Case of Skin Disturbances If the operation cannot be performed after one week on account of skin disturbances or for other reasons, exercises on the knee flexion apparatus (Vol II/figs 1574, 1575) should be started on the eighth day If these exercises are omitted for some weeks, severe limitation of flexion will, as a rule, result

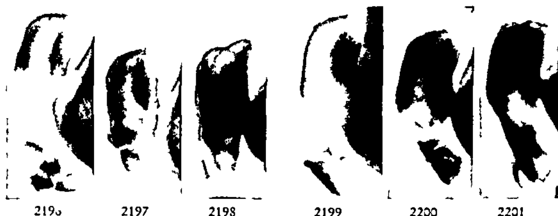
The following are required for the *operation of a fractured patella*

1 Good X-rays
2 Fast developer (see Vol II/p 1253)
3 General, local, or spinal anesthesia
4 The usual general instruments
5 Two strong single-prong hooks

6 30 cm long, 1 mm thick stainless steel wire
7 Wire tightener, cutting forceps, curved awl

Anesthesia General, local or spinal anesthesia may be used

Operation The original X rays are displayed in such a way that they can be seen during the operation Without the use of a tourniquet the site of fracture is exposed by a large U shaped incision which is carried below the lowest point of patella Formerly we used a tourniquet, but it is not necessary



2196 Aug 15 1927 | 2197 Aug 18 1927 | 2198 Oct 29 1936 | 2199 Jan 16 1934 | 2200 Feb 27 1934 | 2201 Oct 29 1936

Fig 2196 —Fracture of the lower third of the patella with wide separation of the fragments. The lower fragment is comminuted Sustained by a 54 year old mason who slipped on the road and fell

Fig 2197 —Check X ray re fig 2196 after operation The fragments are well apposed On discharge from hospital 10 weeks after the injury motion ranged only from 180° to 160° because exercises had been started too early

Fig 2198 —Check X ray re figs 2196 2197 nine years later Bony union in good position The patient now 63 years of age has a range of motion of from 180° to 63° as against 180° to 40° on the sound side

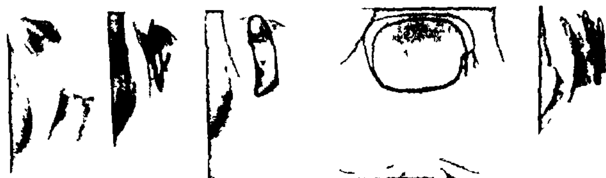
Fig 2199 —Fracture through the lower third of the patella with wide separation of the fragments The lower fragment is comminuted Sustained by a 55 year old man who slipped and fell on his knee while delivering bread

Fig 2200 —Check X ray re fig 2199 six weeks later The fragments have again separated in spite of the silk suture

Fig 2201 —Check X ray re figs 2199 2200 18 months later The patella has united with elongation Bony union has occurred even though the fragments did not touch each other Range of motion 180° to 85° as compared to 180° to 55° on the sound side Tires quickly

as hemorrhage is only slight After severing the skin, fat and superficial fascia with one sweep both skin edges are covered with sterile towels which are fastened by towel clip The skin flap is lifted with a sharp retractor and can usually be pushed upward with gauze This exposes the fragments which are more or less widely separated Sometimes the superficial fascia is intact at the sides Not until this has been cut can one see that the vastus medialis and lateralis are partly or wholly torn After the knee joint has been cleared of fluid and clotted blood by sponging the edges of the extensor tendon are carefully exposed on the upper and lower parts of the patella, and the shreds hanging into the joint are removed with scissors (figs 2186 2187)

Then a 2 cm longitudinal incision is made through the extensor tendon down to bone and the edges of the fragments The anterior edges of both fragments are carefully exposed for 5—6 mm On both sides of the patella



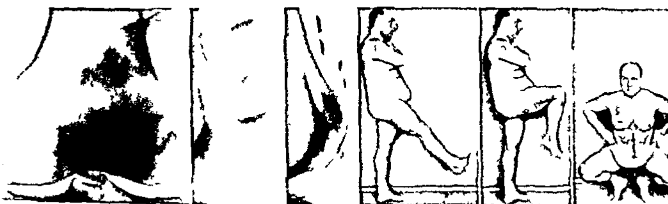
2202 Jan 16 1952 2203 Feb 28 1952 2204 April 9 1952 2205 2206 June 10, 1954

Fig 2202 —Transverse fracture of the patella proximal to its center Sustained by a 44 year old laborer who fell when running in the street Seven days later a wire suture was applied A hole was drilled into the lower fragment the upper fragment was encircled The extensor mechanism was sutured with silk

Fig 2203 —Check X ray re fig 2202 six weeks later The fragments are well apposed The wire suture lies in the posterior instead of the anterior half of the bone The upper fragment is denser than the lower one

Fig 2204 —Check X ray re fig 2203 one week later Following a jump the fragments came apart because the wire was located too far posteriorly The wire did not break The fragments gape anteriorly more than posteriorly Re suture with two anterior wire loops

Fig 2205 2206 —Check X rays re fig 2202 two and a half years later The fragments are accurately apposed and have healed with bony union Equal density Both wires lie in the anterior half of the bone



2207 May 1 1939 2208 June 10 1954 2209 September 10 1939

Fig 2207 —Comminuted fracture of right patella Anteroposterior and lateral view Sustained by a 50 year old man weighing 92 kg in an automobile accident Severe displacement of the fragments They were removed one week after the injury Nine days later an Unna s paste dressing was applied from the web of the toes to the knee for four weeks

Fig 2208 —Check X ray re fig 2207 15 years later Multiple small calcifications in the region of the former patella

Fig 2209 —Photographs of fig 2207 four months later No swelling of the knee Strong muscles Free range of motion Asymptomatic 15 years later

6 30 cm long, 1 mm thick stainless steel wire
7 Wire tightener, cutting forceps, curved awl

Anesthesia General, local, or spinal anesthesia may be used

Operation The original X-rays are displayed in such a way that they can be seen during the operation Without the use of a tourniquet, the site of fracture is exposed by a large U shaped incision which is carried below the lowest point of patella Formerly we used a tourniquet, but it is not necessary

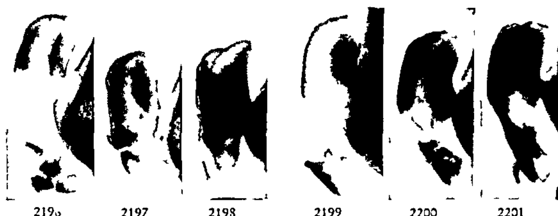


Fig 2196 —Fracture of the lower third of the patella with wide separation of the fragments The lower fragment is comminuted Sustained by a 54 year old mason who slipped on the road and fell

Fig 2197 —Check X ray re fig 2196 after operation The fragments are well apposed On discharge from hospital 10 weeks after the injury motion ranged only from 180° to 160° because exercises had been started too early

Fig 2198 —Check X ray re figs 2196 2197 nine years later Bony union in good position The *patient now 63 years of age has a range of motion of from 180° to 63° as against 180° to 40°* on the sound side

Fig 2199 —Fracture through the lower third of the patella with wide separation of the fragments The lower fragment is comminuted Sustained by a 55 year old man who slipped and fell on his knee while delivering bread

Fig 2200 —Check X ray re fig 2199 six weeks later The fragments have again separated in spite of the silk suture

Fig 2201 —Check X ray re figs 2199 2200 18 months later The patella has united with elongation Bony union has occurred even though the fragments did not touch each other Range of motion 180° to 85° as compared to 180° to 55° on the sound side Tires quickly

as hemorrhage is only slight After severing the skin, fat and superficial fascia with one sweep, both skin edges are covered with sterile towels which are fastened by towel clips The skin flap is lifted with a sharp retractor and can usually be pushed upward with gauze This exposes the fragments, which are more or less widely separated Sometimes the superficial fascia is intact at the sides Not until this has been cut can one see that the vastus medialis and lateralis are partly or wholly torn After the knee joint has been cleared of fluid and clotted blood by sponging the edges of the extensor tendon are carefully exposed on the upper and lower parts of the patella, and the shreds hanging into the joint are removed with scissors (figs 2186, 2187)

If the distal fragment is small or has been partially removed so that only the tip of the lower pole remains, a hole is drilled through the proximal fragment only, and the wire is passed around the distal fragment Since the tip sometimes cannot be seen a needle is used to probe for it This needle will be left in place to indicate where the wire should be introduced This should be done with a curved awl

Reduction of the Fragments and Tying of the Wire Suture As soon as the wire suture has been placed, the fragments are exactly apposed by means of the two sharp hooks The wire is then twisted with the wire tightener



2209 d
June 20 1934



2209 e
December 19 1934



2209 f
June 12 1941

Fig 2209 d —*Open* comminuted fracture of right patella Sustained by a 31 year old telegraph worker who fell from the second floor He also had a cerebral concussion and a closed fracture of the left femur The patella could not be sutured before the 95th day due to skin necrosis

Fig 2209 e —Check X ray re fig 2209 d taken six months later and three months after operation appears to be a non union

Fig 2209 f —Check X ray re fig 2209 e six and a half years later The gap has disappeared Bony union of the patella has occurred The patella is elongated and apparently displaced distally Motion 175° to 110° as compared to 180° to 95° on the other side

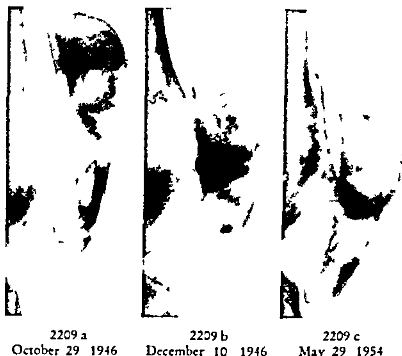
X-ray Since even in the open wound one cannot always determine whether the fragments are properly aligned at the articular surface, a lateral X-ray is taken The film cassette is put in a sterile bag To save time a fast developer is used (see Vol II/p 1253)

Suture of the Extensor Mechanism If the lateral X-ray shows good position of the fragments, the torn vastus medialis and lateralis are sutured by mattress stitches with stout silk thread The aponeurosis of the rectus is sewn with fine stitches over the patella Then the superficial fascia and the skin are sutured

longitudinal incisions are made into the extensor mechanism to get a good survey for reduction and placement of drill holes for the wire suture

A severely comminuted patella should be removed (figs 2207—2209)

Placement of the Wire Suture Formerly we sutured the patella with silk If the suture is placed too far dorsally, angulation may occur later (fig 2190) At present we use 1 mm thick, stainless steel wire Wire has the advantage that it can be tightened more firmly than silk, and that its position can be seen



2209 a October 29 1946 — 2209 b December 10 1946 — 2209 c May 29 1954

Fig 2209 a —Recent comminuted fracture of left patella Sustained by a 51 year old policeman who fell 3 M from a ladder The four fragments were sutured with silk in good alignment

Fig 2209 b —Check X ray re fig 2209 a six weeks later The fragments have united in good position. Decalcification of upper and lower fragments whereas the intermediate one has increased density It has probably become necrotic

Fig 2209 c —Check X ray re figs 2209 a b eight years later Exceptionally low position of patella. The intermediate fragment has remained dense Irregular outline of the lower half of the cartilaginous surface Motion 170° to 160° as against 170° to 45° on the right side In such cases it is much better to excise the whole patella than to include a free piece of bone with the suture

in the X-ray In transverse fractures through the middle part of the patella holes are drilled through both fragments near the anterior surface 1—1 5 cm from the fracture surfaces (figs 2206 and 2228) If the wire is placed in the dorsal half of the bone the fragments might later separate anteriorly (fig 2204)

If the *proximal fragment is smaller than the distal*, the suture is passed round the entire upper fragment by means of an awl (figs 2206, 2228)

If an intermediate fragment has lost all connection with the surrounding tissue it should be removed, as it would become necrotic and cause arthrotic changes (figs 2209 a—c)

air and diathermy are usually agreeable The joint swelling will remain for some weeks or months and will, as a rule, disappear more quickly, if no vigorous measures are employed

Forceful massage and energetic passive motion should be omitted as these irritate the joint Energetic passive movements have more than once pulled the patella apart again We have seen patients in whom this happened not once but twice in one year

Functional Results With this treatment full active extension is always present immediately on removal of the plaster cylinder The knee can be flexed to a right angle usually in 2—4 weeks It may take longer in elderly people That good mobility can result even in old people can be seen in figures 2194, 2195 Depending on the severity of the injury some thickening and swelling will remain for two to four months During aftertreatment particular care must be taken to avoid any flexion contracture, as this will greatly limit the ability to walk Flexion contracture can be abolished by application of a sand bag

In some cases broadening of the patella results from ossification of torn muscles adjoining the fracture site (fig 2219) Lateral motion of the patella is then limited

Excision of the Fragments in Comminuted Fractures of the Patella

If the patella has broken into many small fragments and is severely displaced, the fragments cannot be accurately apposed Arthrotic changes may follow Brooke and Hey Groves suggested excision of the patella and suture of the extensor mechanism in such cases We have often carried out this operation Most patients have regained a full range of motion while limited motion is a common result of non-operative treatment of such cases (figs 2207—2209) In all, however a muscular atrophy of 1—3 cm and decrease of muscular strength resulted In some cases we removed a third or a half of the patella The results were poor

Unsuitable Treatment in Closed Fractures of the Patella With Separation of the Fragments

Physiotherapy Without Suture of the Extensor Mechanism With separation of the fragments, bony union and a full range of active extension, and thus good usefulness of the knee, can only be achieved by suture of the extensor mechanism Massage and electric stimulation without operation are useless If such treatment has been energetically carried out, the joint will remain swollen for a long time X-ray therapy will not reduce such swelling

Callus-forming remedies, often given in such cases, cannot be effective so long as the fragments do not touch each other, and once the fragments are in contact these remedies are not necessary Besides, there are no true callus-forming remedies

Suture of Patella with Thin Wire Without Suture of the Extensor Mechanism Such wires, as a rule, break, and fresh displacement will ensue (fig 2213) If they have been passed through the joint, arthrotic changes will result

Positioning the Leg After application of a compression bandage, the leg is again placed on a Braun splint If the fragments are well sutured they will not separate in this position of slight flexion Formerly postoperatively we immobilized the leg with knee extended on a Cramer wire splint or in a plaster cast The use of a Braun splint is simpler and much more comfortable for the patient

Application of the Plaster Cylinder After eight days the sutures are removed If the wound has healed without complication, an Unna s paste dressing and a plaster cast are applied (see p 1514) with the knee extended (figs 2175—2177)

Exercises With the cast the patient can start walking at once In the first week he should walk a total distance of at least 1 km a day but not all at once, increasing the distance by 1 km each week *if this causes no pain* In addition he should practice raising his leg to the horizontal position while standing Exercising the whole body should not be omitted

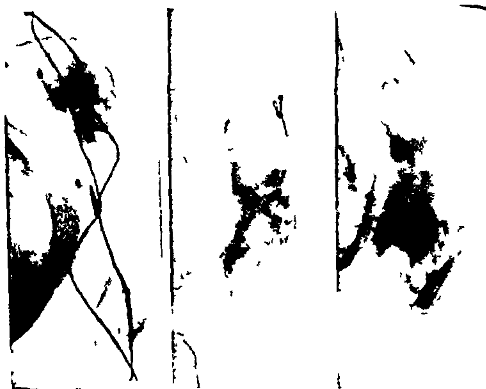
If the patient is allowed to walk with the plaster cast there is no danger of the knee becoming stiff, or of quadriceps atrophy, because the muscles are powerfully stimulated in walking By actively lifting the leg weighted with a plaster cast, the muscles are further strengthened, much more so than by massage The patella is moved up and down over the underlying structures and so cannot become adherent The entire quadriceps, including the fibers which insert into the capsule of the joint (M vastus intermedius), contracts, and keeps the suprapatellar pouch mobile

Figures 2194, 2195, showing the knee of a 79 year old man prove that even in elderly people immobilization in a plaster cylinder does not lead to stiffening of the knee Figures 2196—2198, on the other hand show a 54 year old patient whose range of motion of the knee after 10 weeks is only 20°, because he was not immobilized, and because his knee was irritated by early exercise When the exercises were stopped, the range of motion quickly increased It was 180° to 60° on first follow-up examination

Period of Immobilization If the fragments are well apposed as in figures 2189 2192, 2197 the plaster cylinder is retained for three weeks If a gap has remained between the fragments, as in figure 2200 the cast should not be removed earlier than 4—5 weeks after operation If the plaster cast is taken off too soon and knee exercises begun, angulation might take place between the two fragments as shown in figure 2190 This angulation occurs especially if the wire suture is passed through the dorsal half of the bone as in figures 2203, 2204 instead of through the ventral half as in figures 2206 2228 Good position of the fragments remains undisturbed if immobilization is maintained long enough (figs 2193 2198)

Aftercare On removal of the plaster cylinder the joint is usually moderately swollen, especially if the fragments were widely separated An Unna s paste dressing is applied from the toes to the knee An elastic bandage is worn over this during the day The knee is exercised on the knee flexion apparatus (Vol II/figs 1574, 1575) five minutes twice daily, and the time is increased by five minutes every day (see Vol II/p 1207) If the knee swells, exercise is *decreased* If *the knee* becomes hot moist compresses are applied at night Hot

flexion It was the cause of the muscle atrophy persisting one year after the accident, of the limitation of flexion, and of the bony decalcification The knee cage could be of value only in the case of an injury to the collateral ligaments with lateral instability of the knee Massage, passive movements, and irradiation all could not stop the development of muscle and bone atrophy in that strong young man



2213 November 14 1927 | 2214 January 22 1928 | 2214 a February 14 1952

FIG 2213 —Recent fracture of the patella after wire suture The extensor mechanism had not been sutured in two previous operations and the thin silver wire was incapable of bearing the weight of the body

FIG 2214 —Check X ray re fig 2213 ten weeks later The wire was removed The fragments of the patella and the extensor mechanism were freshened and sutured After this the fragments lay in good apposition and united by bone

FIG 2214 a —Check X ray re figs 2213 2214 25 years later The patella has become larger and more dense Motion 165° to 65° as against 170° to 60° on the sound right side Has resumed his occupation as locksmith

Enclosure of Patella with Fascia Since some surgeons have frequently observed non-union after suture of the patella, they believed that the cause was contact of the fracture surfaces with synovial fluid They, therefore, placed a fascial strip around the fragments to separate them from the joint However the fact that all fractures with good apposition unite firmly, proves that the synovial fluid is not the cause of non-union Bony union occurs even in fractures with slight separation of the fragments, if the extensor mechanism has been sutured (figs 2199—2201)

Wire loops applied in the sagittal instead of the frontal plane and encompassing only small parts of the fracture ends, are also unsatisfactory They cut through the bone as in figures 2232, 2233 and fresh displacement occurs

Sufficiently strong wire must be used for the wire suture and the wire must be accurately guided along the bone, as shown in figures 2228, 2229, and not some distance from it as in figure 2213

The Use of Knee Cages A 26 year old policeman sustained a fracture of the patella during gymnastics It was at once sutured with thin wire which did not lie next to the bone Then he was treated with massage passive movements and irradiation for five months Moreover he received an orthopedic splint which was to be a safeguard against re fracture



2210 March 29 1930 — 2211 April 26 1930 — 2212 November 15 1932

Fig 2210—*Open* fracture of the patella produced by a fall on a rock The fragments are in contact posteriorly but gape 10 mm anteriorly Angular displacement of the articular surface of the patella The extensor mechanism was only slightly torn

Fig 2211—Check X ray re fig 2210 four weeks later The wound was carefully excised the fragments brought into apposition and only the skin sutured without burying any deep sutures Treatment by a plaster cylinder for eight weeks

Fig 2212—Check X ray re figs 2210 2211 two years later Firm bony union of the fragments in good position with smooth articular surface The fracture line is still visible Complete recovery of function

When he was about to resume work he slipped because he was severely handicapped by the splint and re fractured his patella The patella was at once re sutured with thin wire Then he had to wear the orthopedic splint again Further treatment was the same as after the first operation When I saw him 11 months after the first operation and 6 months after the second operation the right leg was much weaker than the sound left leg The knee could be flexed to only 90°

The bones were decalcified He came because he was threatened with retirement if he was not fit for duty within two months I had him discard the orthopedic splint and after a few weeks his leg was again strong and showed good range of motion An X ray taken three years later showed that the thin wire had again pulled through

Re-fracture in this case was due to suture of only the patella with thin wire without suture of the extensor mechanism and to impediment of the joint by the knee cage The splint is purposeless since it will not prevent sudden

skin It would have been necessary to immobilize the knee for four weeks after an operation Thus in his case immobilization in plaster for four more weeks also resulted in bony union (fig 2212) If the fragments had been widely separated, bony union could have been achieved only by operation The fact that the knee had a full range of motion after a year shows that the long immobilization had done no harm

Case 2 At the same time we saw another skier (a world champion) who had broken his knee-cap five months previously He was brought to us on account of severe infection The fracture had been closed but the skin had a superficial abrasion He had been operated upon eight days after the injury although a crust was still present The patella was sutured with wire The leg was placed on a Braun splint A superficial infection developed In spite of this he was allowed up on the eighteenth day without external fixation The wound continued to suppurate and walking was difficult For this reason on the twentieth day the plaster cast was applied Altough the wound was still suppurating when this was removed he was advised to exercise Two abscesses developed one of which evacuated itself while the other was incised After four months the sinuses were scraped out because suppuration was worse Four days later energetic passive movement was begun and the patient had to climb stairs The suppuration became worse and after a week the sinuses were once more scraped out The knee then became more swollen and the patient s general condition deteriorated The leg was laid on a pillow When we saw the patient ten days later the knee was markedly swollen and pus was coming from two sinuses He was emaciated appetite was poor and there was frequent vomiting the skin was yellow The knee joint was in position of 140° flexion On opening the wound the knee joint was seen to be suppurating A plaster cast was applied The temperature never rose above 37 5 C For a time because of the vomiting and cachectic color in the absence of fever we thought he might have a carcinoma of the stomach Investigations however were negative As in the next few days the general condition became worse and the leg suddenly swelled amputation through the thigh was performed The wound was closed with three sutures But the general condition continued to be poor for four weeks The patient then made a good recovery Later he resumed skiing with an artificial leg Dissection of the leg showed a destruction of the cartilage of the medial condyle of the tibia and a perforation of the capsule scarcely large enough to admit a pencil extending back into the posterior medial pouch of the joint The pus had extended from this position under the tendinous arch to between the gastrocnemius and the soleus muscle

If the original operation had been delayed until the superficial wound had healed, there would probably have been no suppuration of the deep stitches Walking without external fixation of the knee on the eigteenth day was an error A further error was the course of exercises Abscesses developed as the result The sinuses should not have been curetted after four months, but carefully exposed in a bloodless field After the curettage, the leg should have been kept at rest Instead it was vigorously moved When the sinuses were explored the second time the knee joint appears to have been entered, still no fixation was provided

Infected Fractures of the Patella

Superficial Suppuration If following the suture of a fractured patella, superficial suppurating sinuses develop, these should not be blindly curetted as in the case above Before the operation the discharge from the sinus should be tested for sensitivity to penicillin and other antibiotics Administration of the appropriate antibiotic is begun the day before operation The sinuses are completely laid open under general anesthesia in a bloodless field maintained by tourniquet All deep stitches are removed Great care should be taken to

Fresh Open Fractures of the Patella

When not only is the patella fractured but the skin damaged, as may happen in a fall from a motorcycle, or in cases of re fracture, where the scar has become adherent to the broken bone, or in those cases where the wound is very dirty, the wound should be carefully excised (see Vol I/pp 142—174) and the smallest foreign body and all crushed tissue removed The joint is swabbed out, and the skin alone sutured The torn extensor mechanism is not sutured, so that no foreign bodies are buried in tissues where there is danger of infection No antiseptic fluids are poured in the joint because these may do much damage Clairmont, for example, reports that he has seen two fatal cases after the use of Chlumsky s solution in open fractures of the patella, necrosis of the tissues having occurred) Then a plaster cylinder is applied and at once split and windowed, and the leg placed on an oblique splint The fore foot is suspended Two to four weeks later, when the wound is healed and the skin normal, the torn extensor mechanism may be united by a second operation if this is necessary With this method, up to 1936, healing of our 11 recent open fractures of the patella was uneventful

Cases are repeatedly published in which immediate suture of the patella after an open fracture has been followed by good results From this it might be inferred that all recent cases should be immediately sutured The bad results however are generally not published

Within a short period we observed two cases of fractured patella which clearly show that no sutures should be buried in cases in which the skin is damaged

Case 1 A skier 28 years old fell and struck his knee against a stone sustaining an open fracture of the patella It was immediately covered with a sterile dressing and splinted it required three hours to bring him down the mountain and a 125 mile train trip to bring him to us He arrived in the middle of the night eleven hours after his injury He had experienced little pain because of adequate splinting On admission a 6 cm transverse jagged wound was present over the patella in which the distracted fragments of the patella could be seen The wound was of a healthy red color X rays were taken without removing the splint and then under local anesthesia the wound was thoroughly excised and without ligating or suturing the deep tissues the skin closed with interrupted stitches This was done in spite of the fact that twelve hours had elapsed since his injury The leg was placed on a Cramer s splint The drain was removed in 36 hours For the first eight days the evening temperature was 38 5 C and the knee was markedly swollen On the third day only 30 cc of serous fluid could be removed by puncture There was no fluctuation The swelling involved the soft tissues and was not a joint effusion In the second week the temperature did not rise above 38 C and by the twelfth day evening temperature was normal The swelling having disappeared by the sixteenth day an Unna s paste dressing and plaster cast were applied and the patient began to walk As the skin still showed some crusts after four weeks a new cast was applied which was removed eight weeks later X rays showed that the fragments of bone which had come together well after removal of the crushed tissues had united in bony union Twelve weeks later he could bend the knee to 90⁰ and a year after the accident he had full range of movement and could undertake long journeys on skis (figs 2210—2212)

If the wound had not been excised and sutured, infection of the knee joint would probably have occurred If the extensor mechanism had been sutured infection of the joint would probably have taken place An operation four weeks after the injury was not possible because there were still crusts on the

skin It would have been necessary to immobilize the knee for four weeks after an operation Thus in his case immobilization in plaster for four more weeks also resulted in bony union (fig 2212) If the fragments had been widely separated, bony union could have been achieved only by operation The fact that the knee had a full range of motion after a year shows that the long immobilization had done no harm

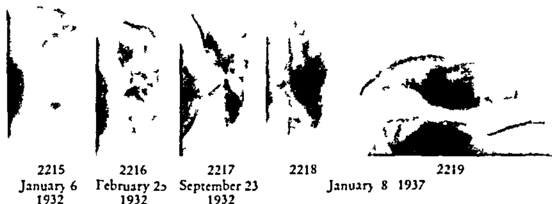
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avoid opening the knee joint When the stitches causing the suppuration have been removed, the wound is firmly packed before removal of the tourniquet If, 5 or 6 minutes after removal of the tourniquet, the pack is removed, there is as a rule only little bleeding Vessels still bleeding are clamped If one removes



2215 January 6 1932 — 2216 February 25 1932 — 2217 September 23 1932 — 2218 — 2219 January 8 1937



2220—2224 January 8 1937

Fig 2215 —Five week old comminuted fracture of right patella with separation of the fragments Sustained by a 29 year old watch maker who fell when skiing He also fractured the ipsilateral femur at the junction of the upper and middle thirds

Fig 2216 —Check X ray re fig 2215 immediately after operation and six weeks after injury Fair apposition of fragments Plaster hip spica for five weeks on account of the fracture of the femur

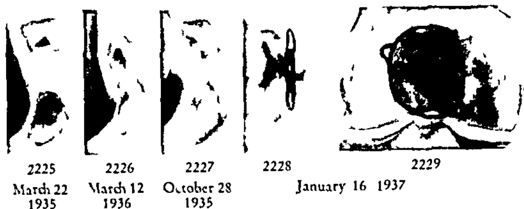
Fig 2217 —Check X ray re figs 2215 2216 eight months later Before operative repair of the extension contracture There seems to be a defect on the posterior surface of the patella At operation the posterior aspect was covered with smooth cartilage No defect could be seen

Fig 2118 —Check X ray re figs 2215—2217 five years later The bony defect of the posterior surface has filled in

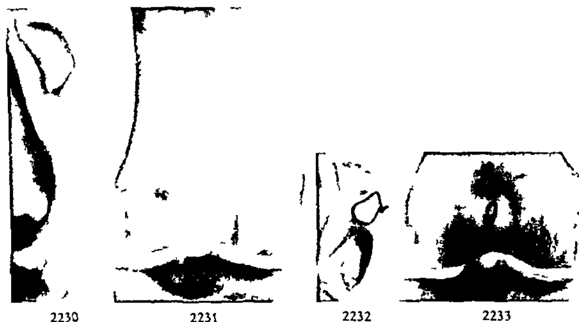
Fig 2219 —Tangential view five years after the injury The patella is much broadened medially

Figs 2220—2224 —Photographs re figs 2215—2219 five years after the injury and four and a half years after the operation for the extension contracture Muscles strong Knee on right side 180° to 45° as against 180° to 40° on the sound side Took up skiing again half a year after operation and has taken part in many races since Asymptomatic

the clamps after a few minutes, bleeding will have stopped No ligatures should be buried, as these foster continued suppuration The skin is closed by a few loose sutures The leg is then placed on a Braun splint or a cushion



2225 March 22 1935 — 2226 March 12 1936 — 2227 October 28 1935 — 2228, 2229 January 16 1937



2230, 2231 July 24 1934 — 2232, 2233 January 11, 1932

Fig 2225 —Non union of the patella seven months after injury Gap of 4 cm between the fragments The fracture surfaces are sclerosed The patient had been treated with massage passive motion diathermy histamine iontophoresis and X ray therapy Walks with difficulty, the knee giving way The knee is swollen

Fig 2226 —Check X ray re fig 2225 one year later The fragments were freshened and the extensor mechanism sutured with silk Bony union in good position has occurred Knee 180° to 90° Patient walks well

Fig 2227 —Non union of the patella five months after *open* fracture of the patella with concomitant ipsilateral fracture of the femur Decalcification of the lower fragment

Figs 2228 2229 —Check X ray re fig 2227 three months later The fracture surfaces are freshened and sutured anteriorly with stainless steel wire Bony union in good position

Figs 2230 2231 —Twelve year old non union of the patella Gap of 14 cm between the fragments Considerable dropping of the lower fragment due to shortening of the patellar ligament Gait uncertain

Figs 2232 2233 —Poorly applied wire suture The loop is much too small and lies in a sagittal instead of a frontal plane The loop has therefore cut through and the fragments have again separated The wire end has not been bent back it projects beneath the skin and causes pain

Deep Infection of the Knee Joint If the patient comes with a wound which is already septic, or if infection of the joint occurs after operation, a plaster cast including the pelvis should be applied in order to give complete immobilization to the knee joint The joint is also aspirated Penicillin is administered locally and generally, if necessary other antibiotics

If, in spite of this, the temperature does not fall to normal, incision is made into the suprapatellar pouch on each side Dorsal incisions into the joint are rarely necessary with the use of antibiotics

If the lower leg suddenly swells up, the pus has broken through the back of the joint as described in the case history on page 1533 In this case the patient can sometimes only be saved by early amputation If the leg can be saved and the X-rays show that the cartilage has been destroyed, arthrodesis is, as a rule, indicated

Origin, Prevention and Treatment of Early Complications Following Fractures of the Patella

Early complications after fractures of the patella are 1 Infection 2 Amputation 3 Death

Infection may follow open fractures and operation in closed fractures Infection can be avoided if, in open fractures, the wound is carefully excised within 6 to 12 hours and if the skin alone is sutured without placing sutures or ligatures in the deeper tissues Antibiotics are given

Infection after operation of closed fractures most often occurs if the operation is performed when after superficial abrasions, crusts are still present on the skin Operation in closed fractures of the patella may be carried out only if the skin is normal

Amputation only becomes necessary as a consequence of infection

Death as a consequence of shock only occurs with concomitant injuries Death also occurs from pulmonary embolism and from sepsis following infection

Death from shock can often be avoided if it is combated by early local anesthesia of the sites of injury, application of warmth, and, if necessary, blood transfusion or plasma

Origin, Prevention and Treatment of Late Complications Following Fractures of the Patella

Late complications after fractures of the patella are 1 Refracture 2 Non union 3 Arthrosis 4 Limitation of motion 5 Muscule atrophy 6 Pain

Re-fracture of the patella is rare In 545 recent fractures we have seen it only three times It results from poor surgical technique especially use of too thin a wire and omission of suture of the extensor mechanism (figs 2204 2213)

Non-Union of the Patella

Origin Without operation fractures with wide separation of the fragments always end in non union If the patella alone is sutured without repairing the extensor mechanism the fragments often separate due to breakage of the wire

In old cases the gap between the fragments may be as much as 14 cm (figs 2230, 2231) Non-union of the patella nowadays is rare During 29 years we have operated on only five cases No operation is necessary in non union with only a small gap between the fragments, since bony union may still take place in one to two years (figs 2209 c, f)

Consequences of Non-Union Flexion usually is free, unless the joint has been irritated for months by such exaggerated aftertreatment as forceful massage and energetic passive movements Active extension, however, is lost Impairment depends on the size of the gap between the fragments If this is less than 1 cm, extension is, as a rule, complete If it amounts to more than 1 cm there is usually loss of extension Passive extension is usually, but not always, free The patellar ligament is shortened Therefore the distal fragment is displaced towards the tibia (figs 2225, 2227, and especially 2230) Shortening in the quadriceps is even more marked There is severe atrophy of the extensor muscles The suprapatellar pouch is frequently obliterated The patella is laterally only slightly movable

At operation the two fracture surfaces are found to be sclerosed, and together with the edges of the ruptured muscles are covered by a smooth synovial membrane This is best illustrated in the following case history

Case History We recently saw a case in which a silver wire had first broken ten months after and again sixteen months after operation In both operations (elsewhere) the curved incision had been made with its base downwards As the flap was too narrow the lateral rupture of the extensor mechanism could not be seen Using a long transverse incision two thirds round the joint the broken pieces of wire were exposed and removed The fragments of the patella were found widely separated The second fracture had occurred at a lower level than the first (fig 2213) The vastus medialis and lateralis were torn through their entire width the separated edges of the tear were thickened by scar tissue and covered with synovial membrane so that even had they been approximated they could not have grown together The suprapatellar pouch was obliterated After separating the adhesions excising the edges of the tear in the vasti and freshening the surfaces of the bone fragments the whole of the extensor mechanism was sutured in the same way as in a recent fracture (fig 2214) Bony union ensued At follow up examination 23 years later the knee had a very good range of motion

Treatment Operative treatment of old ununited fractures is possible if the separation of the fragments does not exceed 5—6 cm The operation should be performed under spinal or general anesthesia Local anesthesia is insufficient The two fracture surfaces are freshened with a chisel, and the edges of the torn muscles with a scalpel The adhesions in the suprapatellar pouch are freed By strong pull exerted for some minutes with two sharp hooks it will be possible to bring the fragments into apposition The suture is carried out as in recent fractures (see pp 1526—1527)

If the gap between the fragments exceeds 6 cm as in figure 2230, the fragments cannot be apposed In such a case the sartorius may be transplanted and placed over both fragments according to Schanz, or an operation may be performed as for extension contracture of the knee joint (see Vol II/pp 1474, 1475)

Immobilization, exercises, and further treatment are carried out as in recent fractures of the patella (see pp 1528, 1529) If the cartilage of the patella has

been severely damaged, the patella should be removed and the extensor mechanism sutured

Arthrotic Changes After Fractures of the Patella Severe arthrotic changes are comparatively rare, since the joint between the patella and the femur is a non weight-bearing joint We have observed arthrotic changes in only 4 14% of our patients, mostly after comminuted fractures with incomplete reduction These patellae should therefore be excised primarily Slight arthrotic changes have occurred in 20 80% see p 1542) Most patients of this group had no pain and no limitation of motion

Impaired Motion Following Fractures of the Patella After closed fractures of the patella without separation of the fragments, and after open fractures without subsequent infection, motion of the knee, as a rule, will become normal

After fractures of the patella with separation of the fragments necessitating operative treatment, motion will be good after some months in most cases Extension will seldom be disturbed, flexion will be limited, only if the operation had to be postponed for some reason (figs 2009 d—f) or if in a comminuted fracture the patella was not excised and pieces of bone which had lost all connection with the surrounding tissue were left in place as in figures 2209 a—c

Muscular extension contracture of the knee, as a rule only develops with a simultaneous fracture of the ipsilateral femur It is treated by a quadriceps plasty as described in Vol II/p 1473 Figures 2215—2224 show that under favorable conditions free range of motion can be achieved

Ankylosis of the knee joint following fractures of the patella occurs only as a consequence of infection

Muscle atrophy of more than 2 cm is exceptional (2 1%) in mild fractures without separation of the fragments It more often (14 6%) follows the severe fractures in which the separation of the fragments necessitates operation Muscle atrophy is most severe after complete excision of the patella Muscle atrophy of 2—5 cm was present in six out of nine cases

Severe pain is rare It is seen only in the few cases in which ankylosis has failed to develop after infection In such cases arthrodesis is indicated

Questions We Should Ask Ourselves in Order to Avoid Failures When *Treating Fractures of the Patella*

1 Have I treated fractures without displacement conservatively?
2 Have I in the presence of abrasions or crusts postponed operation until the skin has become normal to avoid infection?
3 Have I used a big curved incision over the tip of the patella with a proximal and not a distal base?
4 Have I made the incision large enough so as to see lateral tears of the extensor mechanism?
5 Have I after exposure of the patella incised both fragments longitudinally for 2 cm and dissected for 5—6 mm to check the exact apposition of the fragments?

6 Have I made longitudinal incisions in the extensor mechanism at both sides of the patella to enable me to accurately place the drill holes and the wire?
7 Have I guided the wire with a curved awl round the tip of the patella if the distal fragment was small?
8 Have I driven a needle into the tip of the patella to find this spot when using the awl?
9 Have I completely excised the patella in case of severe displacement of the fragments?
10 Have I used a strong, stainless, 1 mm thick wire for the wire suture?
11 Have I placed the wire suture in the anterior half of the patella?
12 Have I obtained a lateral X-ray and had it developed with the rapid developer after reduction of the fragments and application of the wire suture?
13 Have I carefully sutured the extensor mechanism in front and at both sides of the patella as soon as the X-ray showed good position of the fragments?
14 Have I applied a compression bandage and placed the leg without a plaster cast on a Braun splint or a pillow?
15 Have I applied an Unna's paste dressing and a plaster cylinder after 8 to 10 days?
16 Have adequate exercises (walking and raising the leg up to the horizontal) been performed faithfully, if they do not cause pain?
17 Has the plaster cast been removed five weeks after the operation?
18 Have massage and passive movements been omitted, since they irritate the joint and thus lead to limitation of motion and sometimes to re-fracture of the patella with rupture of the extensor mechanism?
19 Have I omitted curetting superficial draining sinuses, but exposed the site of suture and removed the infected stitches?
20 Have I, in infection of the knee joint, applied a fenestrated plaster hip spica and given antibiotics?
21 Have I aspirated the joint and administered penicillin and, if necessary, other antibiotics, locally?
22 Have I amputated at the proper time if infection has spread beyond the joint and generalized sepsis developed?

End-Results of Fractures of the Patella

Schonbauer has re-examined our 574 patients with fractures of the patella of the years 1926—1952 Four of these patients had sustained bilateral fractures of the patella, thus, 578 recent fractures of the patella were treated In these 27 years we have admitted 74,463 in patients Thus the incidence of fracture of the patella was 0 8%

Age Our youngest patient was 12 years old and the oldest 83 The average age was 42 4 years

Type of Fracture Of the 578 fractures, 545 were recent, 33 cases were old fractures, non unions, re-fractures, and secondary fractures

Of the 545 recent fractures 488 (89 5%) were closed, and 57 (10 5%) open fractures

Distribution of Types of Fracture in the 545 Recent Fractures Of the 488 closed fractures 387 (79 3%) were transverse 58 (11 9%) longitudinal, and 43 (8 8%) stellate and comminuted fractures

Of the 57 open fractures 36 (63 2%) were transverse, 10 (17 5%) longitudinal, 4 (17 0%) gunshot and 7 (12 2%) stellate and comminuted fractures

Method of Treatment Of the 488 recent closed fractures, 328 (67 2%) were treated conservatively and 160 (32 8%) operatively

Deaths Of the 488 recent closed fractures one patient, whose patella was excised, died (0 2%) of pulmonary embolism on the 19th day Among the 57 recent open fractures one patient died (1 75%) also of pulmonary embolism on the 33rd day

Wound Healing Of 160 operated recent closed fractures healing occurred

per primam	147 (91 9 %)
p p with necrosis of skin	5 (3 1 %)
per secundam without infection of the joint	2 (1 25%)
empyema of the joint	6 (3 75%) in which

there was one amputation and four cases of ankylosis In no other kind of injury have we had such a great number of infections They occurred chiefly when the operation was carried out before the skin had completely recovered after deep excoriations

Of 57 recent open fractures healing took place

p p	50 (87 7%)
p p with necrosis of skin	5 (8 8%)
with empyema	2 (3 5%) of which

there was one amputation and one ankylosis

Stitch abscesses occurred 13 times (8 1%) in 160 operated recent closed fractures and twice (16 6%) in 12 recent open fractures, in which suture of the patella was performed End-results were unaffected

Duration of Treatment Because of severe associated injuries and diseases 52 of the 488 closed fractures and 24 of the 57 open fractures were excluded

Average time of treatment was

69 days in 301 recent closed fractures treated conservatively,
137 1 days in 135 recent closed fractures treated operatively,
126 8 days in 21 recent open fractures without suture of patella,
173 2 days in 12 recent open fractures with suture of patella

Since only the more severe cases were operated upon treatment of operated patients took longer

End-Results

Of the 488 recent closed fractures clinical and radiological re examination was carried out in 297 (60 9%), of the 57 recent open fractures in 33 (57 9%) patients Re-examination took place 2 to 24 years after the injury, i e after an average time of 8 years

Fracture Healing

Closed Fractures

treated conservatively	bony union	198 (96 6%)
	non-union	7 (3 4%)
	Non unions occurred only in longitudinal or oblique fractures	
treated operatively	bony union	75 (81 5%)
	non-union	4 (4 3%)
	(one of these cases was a tabetic patient)	
	excision of distal fragment only	6 (6 5%)
	total excision of patella	7 (7 6%)

Open Fractures

bony union	24 (72 7%)
non-union	6 (18 2%)
(of which 2 cases were operated)	
total excision	3 (9 1%)

Motion

Among the 274 re-examined recent closed fractures without associated injuries there was

full extension in	270 (98 5%)
10°—20° loss of extension in	4 (1 5%)
full flexion in	240 (87 6%)
10°—20° loss of flexion in	23 (8 4%)
flexion from 180° to 80° in	3 (1 1%)
flexion from 180° to 90° or less in	8 (2 9%)

Among 22 re-examined recent open fractures without concomitant injuries there was

full extension in	22 (100 %)
full flexion in	17 (77 2%)
10°—20° loss flexion in	4 (18 2%)
flexion from 180° to 90° or less in	1 (4 5%)

Quadriceps atrophy

In nine cases the measurements were of no value because of injuries to the other leg

In 189 cases treated conservatively there was

no muscle atrophy in	139 (73 5%)
wasting of 1—2 cm in	46 (24 3%)
wasting of 2—5 cm in	4 (2 1%)

In 89 operative cases there was

no wasting in	31 (34 8%)
wasting of 1—2 cm in	45 (50 6%)
wasting of 2—5 cm in	13 (14 6%)

In 9 cases of total excision there was

no wasting in	0 (0 %)
wasting of 1—2 cm in	3 (33 3%)
wasting of 2—5 cm in	6 (66 7%)

Arthrotic Changes

In this group were included all those cases in which X-rays showed marginal exostoses of the patella, or of the patella and the femoral and tibial condyles.

Of 274 re-examined recent closed fractures without concomitant injuries *conservative treatment was followed by*

no arthrotic changes in	169 (87.1 %)
slight arthrotic changes in	22 (11.3 %)
severe arthrotic changes in	3 (1.55%)

Operative treatment was followed by

no arthrotic changes in	34 (45.95%)



2234 July 7 1934 2235

FIG 2234.—Lateral dislocation of patella anterior view

FIG 2235.—Same case in half external rotation

slight arthrotic changes in	33 (44.6 %)
severe arthrotic changes in	7 (9.5 %)

Total excision was followed by

no arthrotic changes in	3 (50.0%)
slight arthrotic changes in	2 (33.3%)
severe arthrotic changes in	1 (16.7%)

Of the entire group of 274 cases there were

no arthrotic changes in	206 (75.2 %)
slight arthrotic changes in	57 (20.8 %)
severe arthrotic changes in	11 (4.15%)

Among the 22 re-examined recent open fractures without concomitant injuries there were

no arthrotic changes in	15 (68.2%)
slight arthrotic changes in	7 (31.8%)

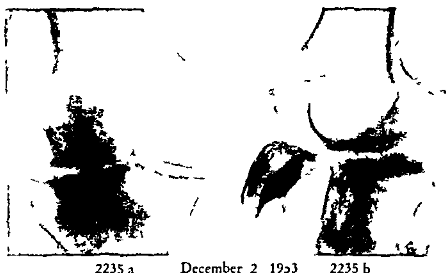
AVULSIONS OF THE TIBIAL TUBEROSITY

In 620 injuries of the extensor mechanism we have found only nine avulsions of the tibial tuberosity, only two of which were severely displaced, and in these the tibial tuberosity was fixed with a screw All nine cases healed with a full range of motion

77 TRAUMATIC DISLOCATION OF THE PATELLA

Origin Dislocation of the patella occurs following sudden contraction of the muscles with the lower leg abducted and rotated externally It usually occurs only in people with an abnormal valgus position of the knee associated with an underdeveloped lateral condylar ridge of the femur

Displacement in Dislocation of the Patella Due to the physiological valgus



2235 a December 2 1953 2235 b

Figs 2235 a b —Unusual distal dislocation of the patella with severe valgus of the knee Rectus tendon not ruptured Dorsal subluxation of the lower leg Sustained by a 50 year old woman who fell in the road At the age of 33 she was operated for recurrent dislocation of patella according to the method of Ali Krogius

position of the knee, the patella may be displaced in a lateral direction either parallel with the anterior surface of the knee or twisted for 45° to 90°, so that the articular cartilage points toward the lateral aspect of the femur (figs 2234, 2235)

Besides the usual lateral dislocation of the patella displacement around the long axis has been described, in which the patella then remains in the intercondylar notch and is twisted 90° to 180° We have never seen such cases and have never found X-rays showing such dislocations in the literature

In addition, so-called horizontal dislocation of the patella has been observed, the patella lying parallel with the joint space of the knee This can only occur if the rectus tendon or the patellar ligament have been ruptured In this condition rupture of the tendon is the essential injury and displacement of the patella is a consequence of the ruptured tendon

An unusual case is depicted in figures 2235 a, b The patella is dislocated caudally without rupture of the rectus tendon and lies in front of the

posteriorly dislocated tibial head Such dislocation is possible only in pathological conditions In this case there had been a habitual dislocation of the patella with considerable valgus and posterior subluxation of the tibia for which the patient had been operated upon 13 years previously

Reduction Reduction is often quite simple, and can usually be achieved without local anesthesia The leg of the recumbent patient, with the knee hyper-



FIG 2236—Shape of the patella in a bilateral recurrent dislocation of the patella The X rays were taken in extreme flexion of the knee with the patient prone and the central ray directed at the femur at right angles. The lateral portion of the patella is broader than normal the medial third of the patella is absent The shape of the articular surface of the patella corresponds to that of the lateral portion of the articular surface of the femur and the patella does not lie in the intercondylar notch but rests against the lateral condyle of the femur The ridge of the normal patella corresponding to the intercondylar notch of (fig 2237) is missing In addition flattening of the lateral femoral condyle is evident as well as a small loose body in the intercondylar notch



FIG 2237—Normal patellae Their articular surfaces fit the intercondylar notch and show the corresponding ridge This will lie in the intercondylar notch even at extreme flexion Note the shape of the condyles. Contrary to fig 2236 the lateral condyles project further than the medial ones (after Krömer Der Chirurg 9 7)

extended and the hip flexed is placed with the foot on the operator s shoulder The quadriceps is thus relaxed The patella can then be replaced by light pressure of the fingers The bone often slips back by itself when the leg is raised

In the patient of figures 2235 a b under general anesthesia the attempt was made to push the posteriorly subluxated tibial head anteriorly This was only partially successful So the patella was grasped with the fingers in order to reduce it At first the patella rotated round its long axis so that its articular cartilage faced laterally On further manipulation it slipped back into place

Immobilization Since dislocation is only possible in the presence of rupture of the vastus medialis at its insertion on the medial aspect of the

patella, there is danger of re-dislocation To avoid it a plaster cylinder is applied for four weeks with the knee extended (see p 1515) and figures 2175—2177)

Exercises and further treatment are carried out as in fractures of the patella (see pp 1528, 1529)

Treatment of the Horizontal Dislocation of the Patella As the essential injury is rupture of the rectus tendon or the patellar ligament, the extensor mechanism must be sutured

Forceful massage and energetic passive movements must be avoided as they irritate the joint and extend the tear at the medial side thus leading to habitual dislocation



FIG 2238 —Left side photograph re fig 2236 22 year old female farm worker who has been suffering from recurrent dislocation of patella for years With every flexion of the knee joints the patellae slipped out at a flexion angle of 90° and slipped back on extension To avoid dislocation flexion beyond a right angle was avoided She was handicapped considerably at work Marked atrophy of the vastus medialis No valgoid position Right side Normal person s legs for comparison After Kromer Der Chirurg 9 7

RECURRENT AND PERMANENT DISLOCATION OF THE PATELLA

If recurrent dislocation of the patella develops following traumatic dislocation, each occurrence of dislocation is connected with pain and subsequent swelling

Moreover, there are two additional types of dislocation that are partly congenital and partly acquired One type is associated with severe valgus position of the knee and the other with congenital under-development of the vastus medialis with a normal knee-axis (fig 2238) Abnormal torsion of the distal end of the femur either laterally or medially is sometimes present If the femoral condyles are twisted medially, the patella is pulled from the sulcus up onto the lateral condylar ridge and slips over it With lateral torsion of the femur the patella slips outwards over the lateral condyle

Since the patellar ligament does not insert as a straight continuation of the rectus tendon but deviates laterally, it would repeatedly slip out laterally, if the vastus medialis, whose fibers run at right angles to the rectus tendon, did not hold it medially Besides, normally the lateral condylar ridge is much higher than the medial one (fig 2237) In congenital recurrent dislocation the lateral condylar ridge is less prominent than the medial (fig 2236) Moreover, the shape of the patella differs in these cases (fig 2236) My former assistent Dr Kromer[1] has described this In these cases the patella slips out at each flexion beyond 90° and slips back in extension Recently we saw a woman whose patella slipped out at the angle of 170° and slipped back at 160° The patella appears round in the lateral X-ray, not oval, and is placed higher than normal

Permanent Dislocation of the Patella Besides these we have seen patients with permanent dislocation of the patella They usually had a normal intercondylar notch, but a complete absence of the vastus medialis

Treatment If this condition causes symptoms, operative treatment offers a cure The shortened lateral capsule should be split and the joint capsule at the medial side of the patella should be reefed and folded In some cases the tibial tubercle should be transplanted with the patellar ligament 3—4 cm medially Sometimes a torsion osteotomy of the femur is necessary

In a 52 year old woman we have successfully removed the severely deformed patella

We performed an operation similar to the quadriceps plasty for extension contracture of the knee (see Vol II/p 1474) The suprapatellar pouch was enlarged proximally medially and laterally to more than twice its size First the vastus medialis and lateralis were detached extensively from the rectus tendon Then the patella was excised and its bed sutured transversely Then the vastus medialis was sutured to the vastus lateralis behind the rectus tendon At the attempt to flex, the sutures cut through So we flexed the knee to a right angle and fastened the vastus medialis to the vastus lateralis with towel clips then completed the suture with the knee in extension The rectus tendon was then sutured to the vasti with the knee at a right angle The end result was good In severe valgus position the tibial tubercle should also be transplanted medially

78 DISLOCATION OF THE KNEE JOINT

This injury is rare In the 23 years from 1926 to 1948 Ender found only 32 cases among our 450,000 patients (70,000 in patients and 380,000 outpatients) Up to 1954 we treated 21 additional cases

Origin Dislocation of the knee joint occurs frequently in elderly men and is produced by a major force either indirectly by a fall (e g from a bicycle), or directly by a blow on the knee or tibial head or by a force exerted on the femur while the lower leg is fixed

[1] Kromer Der Chirurg *9* 88—89 1937
[2] Bohler Ztschr orth Chir *38* 308 623 1917—18

Displacement Theoretically there are five types of dislocation of the knee joint In relation to the femur the lower leg may be displaced laterally, medially, posteriorly or anteriorly, or rotated round the long axis Pure dislocation in only one direction is rare, but occasionally occurs anteriorly or posteriorly We have never seen a pure medial or lateral dislocation The dislocation usually occurs in two directions and is often associated with rotation The dislocations are, as a rule, subluxations Complete dislocations are rare We have observed only five such cases among 32 dislocations of the knee, two posterior (figs 2248 g, h), and three anterior ones (figs 2248 a—d), and none lateral In our experience as at the elbow, lateral dislocation with simultaneous anterior or posterior displacement are most frequent With posterolateral displacement the leg is often in varus position (figs 2253, 2257), with anterolateral displacement in a valgus position (figs 2239—2241, 2252 a—c) A varus position is usually accompanied by internal rotation, valgus with external rotation

Pathology Dislocations of the knee joint are only possible if the capsule is torn, and a collateral or cruciate ligament more or less stretched or torn Since most of the ligaments remain intact, there is a springy fixation of the joint ends If all ligaments are torn, the lower leg can be displaced in all directions (complete joint rupture) The injuries to the ligaments are frequently accompanied by rupture of the popliteus, the heads of the gastrocnemius and especially the vastus medialis In a complete anterior or posterior dislocation the anterior or posterior or both cruciate ligaments are torn, whereas both collateral ligaments may remain intact

Lateral dislocations are always accompanied by tear of the medial collateral ligament The ligament is most frequently torn at its femoral insertion, usually the entire medial portion of the capsule is also ruptured The capsule is drawn into the joint and, covers the medial condyle of the tibia like a cap (figs 2252 d, e) This produces a transverse groove in the skin at the edge of the tibia At operations we also found that the superficial layer of the collateral ligament had been torn at the femoral insertion, whereas the deep layer of the ligament had been torn at the tibial insertion, as shown in figures 2284 a—f

In lateral dislocations with valgus and external rotation of the lower leg the medial condyle of the femur frequently perforates the distal portion of the vastus medialis Its projecting edge can then be seen The skin is tightly stretched and white, and threatens to burst If reduction is delayed, the skin will become necrotic

If the knee is extended the tendons of the pes anserinus (semimembranosus, semitendinosus gracilis and sartorius) slip into the intercondylar notch on the flexor side (figs 2249, 2250)

Sometimes the bony insertions of the cruciate and collateral ligaments or parts of the articular surface of the tibia are avulsed (figs 2257, 2258), or the femoral condyles (figs 2262 a, b) are sheared off This occurs as a rule only in open dislocations

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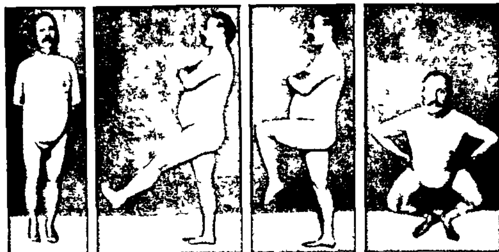
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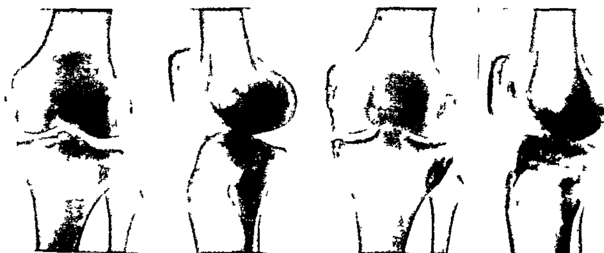
Injuries of the Menisci The menisci may be detached at their base and may occasionally be torn They usually slip back to their normal place on reduction In only one of our cases did they impede reduction

Injuries to Vessels In very severe displacements the popliteal artery may be torn, more often in posterior than in anterior dislocations, gangrene then develops quickly If the artery is compressed, the pulse will also not be palpable If pressure is not relieved early, thrombosis and late sequelae will



2243—2246 December 5 1934

Figs 2243—2246—Comparison photographs re figs 2239 2240 nine months later The 58 year old man has active motion of the knee from 180° to 60° as compared to 180° to 55° on the right side The knee is not swollen the muscles are not atrophic There is no laxity of the joint either laterally or anteriorly or posteriorly He feels no pain although as a customs official he must walk long distances and climb stairs, 20 years later the now 78 year old man shows the same range of motion A slight drawer sign is present



2247 April 8 1936 2248 October 20 1954

Fig 2247—Check X ray re figs 2241 2242 two years later Normal shape of the joint ends No subluxation No arthrotic changes Slight ossification of the ligaments at the upper insertions of both collateral ligaments A small shadow is visible above the tibial spine and near the lower insertion of the posterior cruciate ligament

Fig 2248—Check X ray re fig 2247 eighteen years later No arthrotic exostoses The ossification at the ligamentous insertions has slightly increased





2239 March 1 1934 2240

FIGS 2239 2240—Anterolateral dislocation of the left knee with valgus and 50° external rotation of the lower leg sustained in slipping off a curbstone The skin over the medial femoral condyle is greatly stretched The patella is also dislocated laterally (compare with X rays of figs 2241 2242) Reduction immobilization in a plaster cylinder for twelve weeks



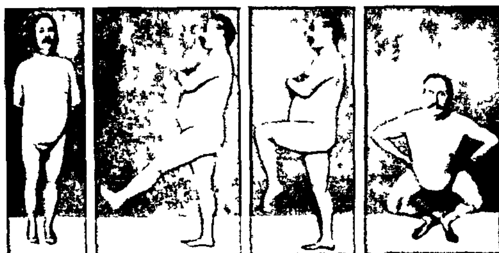


2241 March 1 1934 2242

FIGS 2241 2242—X rays re figs 2239 2240 Lateral dislocation of the tibia by more than the width of a condyle The lateral edge of the femur rests on the articular surface of the medial condyle of the tibia A small piece of bone can be seen above the tibial spine this is the avulsed insertion of a cruciate ligament Such displacement is only possible if both cruciate ligaments are completely torn and the collateral ligaments partly torn

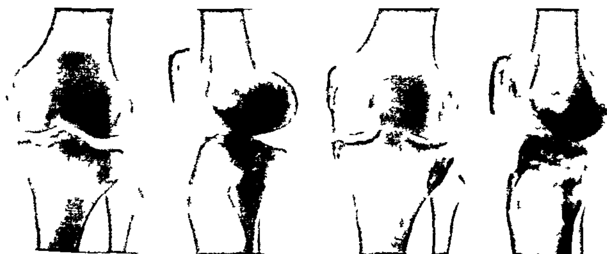
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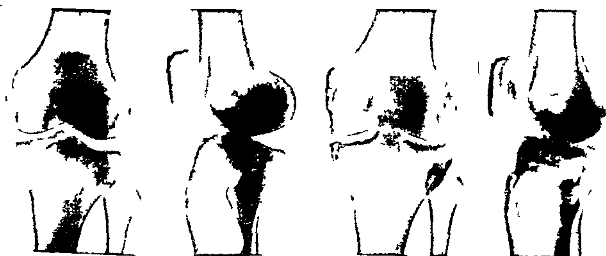
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Injuries to Nerves In the rare medial dislocations the peroneal nerve may be stretched or torn The fibular head may be avulsed and, along with the biceps tendon and capsule, displaced into the joint, as in displacement of the medial epicondyle into the elbow (Vol I/figs 850—857) Among our 32 cases we observed sensory disturbances in three and peroneal palsy in two cases These disturbances quickly disappeared after reduction

Examination Inspection reveals striking distortion of the knee In rupture of the popliteal artery the foot is pale and in compression of the vessels it is blue The pulse is tested on the dorsum of the foot and behind the medial malleolus Active motion of the toes and ankle joints and sensation are compared on the two extremities The stability of the knee is carefully examined without causing pain

Anterior and lateral *X-rays* should be taken in all cases to ascertain the type of dislocation and to determine if there are accompanying bone injuries

Diagnosis is simple since the change of shape and the springy fixation are obvious At the first glance separation of the epiphysis may be mistaken for dislocation of the knee (see figs 1 2 of Kromer s cases[1]) If the skin is stretched over the medial femoral condyle and the tibial head, the vastus medialis is, as a rule perforated by the medial condyle of the femur A transverse fold of skin above the inner margin of the tibial head suggests an interposition of the capsule (figs 2252 a—e) Sometimes the dislocated bone to a large extent slips back *spontaneously*, so *that little remains of the lateral* displacement If a transverse groove remains at the medial side of the joint, it suggests interposition of the capsule in the joint The X ray will then show a widened joint space

A transverse deeply drawn in fold at the extensor side, above the patella, suggests an anterior dislocation with severe displacement (figs 2248 a—d)

Complications Following Dislocations of the Knee Deaths due to sepsis after open dislocations and after operation of closed dislocations used to be reported frequently Some patients die from shock due to accompanying injuries Two of our 32 patients died from shock In rupture of the popliteal artery the leg usually must be amputated If life and leg have been saved *limitation of motion* and *flail joints* may result from improper treatment Extensive *ossification of ligaments* and muscles (Vol I/figs 49—51) occur only after delayed reduction or early massage and passive movements We have never observed ossification in cases reduced within the first day but we found it in three patients in whom reduction was delayed, because they did not come for treatment until 4 to 17 days after the injury Pellegrini Stieda s calcification

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[1] Kromer Behandlung und Ergebnisse der traumatischen Kniegelenksverrenkungen Ergebnisse d Chirurgie u *Orthop 29* 583—626 1936

of medial collateral ligament develops in some cases, but as a rule causes no disturbance.

Treatment. The object of treatment is to reduce the joint gently and as early as possible and immobilize the leg uninterruptedly in 170° of flexion until the torn ligaments have united firmly enough to withstand the strains of weight-bearing. Regular exercises should be carried out throughout the period of immobilization to keep the muscles strong so that a maximum range of joint motion can be restored.

Preparation for Reduction and Fixation. The following are required:

1. Good anterior and lateral X-rays (figs. 2241, 2242, 2248 a—h, 2257, 2258, 2262 a, b).
2. Local anesthesia (see Vol. I/p. 119 and Vol. I/fig. 152) or general anesthesia.
3. A plaster cylinder (figs. 2175—2177).

Anesthesia. General anesthesia is, as a rule, preferable to local anesthesia.

Reduction. The original X-rays, are displayed in such a way that the surgeon can see them. To correct the shortening, traction is exerted in the long axis of the lower leg with the knee bent to a right angle, while countertraction is exerted on the thigh by a helper. This releases the fixation. In anterolateral dislocations the lower leg is then pushed posteromedially, in posterior dislocations it is pushed forwards, and in anterior dislocations it is pushed posteriorly. Rotation is corrected at the same time. Reduction is as a rule easy if the knee is flexed. Longitudinal traction with the knee extended should not be used in complete dislocations with springy fixation of the joint, since the hamstring tendons might be caught in the intercondylar notch and obstruct reduction (fig. 2249, 2250). If the knee is flexed, the tendons will slip out and obstruction will be overcome (figs. 2251, 2252).

Reduction with the knee extended will usually only be successful in joint ruptures. In such cases no anesthesia is required. Under no circumstances should reduction be attempted with the knee in over-extension, since vessels and nerves might be damaged.

Examination of Circulation and Stability of the Joint. If the dorsalis pedis and posterior tibial pulses were absent before reduction, they should be reexamined after reduction. Then the lateral stability (figs. 2167—2170, 2266 to 2268) and the drawer sign (figs. 2269, 2270 and 2284 g—m) are tested.

Irreducible Dislocations of the Knee. Reduction of dislocation of the knee is, as a rule, easy if performed as described above. In some cases of partial posterolateral subluxation reduction must be performed operatively.

Manipulative reduction may fail due to extra or intraarticular obstruction. In anterolateral dislocations the hamstring tendons of the pes anserinus are caught in the intercondylar notch and obstruct reduction completely if the knee is extended (figs. 2249, 2251). With flexion of the knee to a right angle the obstruction disappears (figs. 2250, 2252). Therefore reduction should always be done with the knee in flexion. Furthermore, reduction in extension might damage the popliteal vessels and nerves.

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condyle of the femur and sutured at the place of rupture Then the skin is closed

Dislocations of the Knee with Rupture of Vessels If after reduction, the pulse at the dorsum of the foot and behind the medial malleolus still cannot be felt, if the foot remains pale and cold, and if no color returns at the release of pressure exerted on the nails, these signs will indicate that the popliteal artery is torn or obstructed In such cases arteriography is performed to locate the site of obstruction Then the popliteal fossa is exposed under a tourniquet and a suture of the vessels is attempted Up to now only two cases have been reported in which this operation was successful In all other



2248 e—h April 21 1944

Figs 2248 e—h —Complete posterior dislocation of the left knee with internal rotation of the lower leg and foot Produced by the impact of an anti aircraft gun on the front of the lower leg *The tibial head is displaced posteriorly The femur with the patella project anteriorly* No vessel or nerve disturbances Reduction is, as a rule, easy with traction at the flexed lower leg

cases the leg became gangrenous in spite of suture of the vessels If the artery cannot be sutured, the leg is amputated at once unless, on removal of the tourniquet, bleeding occurs from the distal ends of the vessels indicating intact collateral circulation in which case the vessels should be ligated If the leg remains cold, it should be amputated as soon as demarcation is evident *If the artery is not ruptured but only obstructed by* a thrombus, the thrombus should be removed

First X-ray Control After reduction, exact anteroposterior and lateral X-rays should be taken to be certain of complete reduction To determine the degree of the injury of the collateral ligament, stress X-rays are taken in abduction (fig 2667) Rupture of the cruciate ligaments is shown by stress X-rays in posterior or anterior displacement of the tibia with the knee flexed to a right angle (fig 2284 g—m)

In some cases of postero lateral dislocation of the knee the medial collateral ligament together with the entire medial portion of the capsule are avulsed from their cranial insertion on the femur and are displaced into the joint (figs 2252 d, e) A deeply drawn in transverse fold of skin can then be seen at the medial margin of the tibial head (figs 2252 a, b) The vastus medialis is sometimes perforated by the medial condyle of the femur, and the distal portion of the muscle is caught in the intercondylar notch These cases of interposition can easily be recognized by the transverse fold of skin at the medial side of the joint and no forceful attempts at reduction should made but the joint should be exposed and the obstruction removed

Displacement of the avulsed medial meniscus obstructed reduction in only one of our cases



2248 a—d February 2 1950

Figs 2248 a—d —Complete anterior dislocation of the right knee The right leg is 5 cm shorter than the left one Deeply drawn in transverse skin fold cranial to the patella Sustained by a 58 year old woman who fell from a ladder Color of the foot and motion of toes and ankle joint normal Reduction was achieved easily by longitudinal traction with subsequent flexion Good functional end result

Operative Reduction The joint is exposed medially through an oblique or a longitudinal incision After incision of the skin and subcutaneous tissue, the medial condyle of the femur is seen stripped of all soft tissue covering The capsule, avulsed at its femoral insertion is interposed either with or without a portion of the vastus medialis into the joint-space and covers the medial condyle of the tibia like a cap (figs 2252 d, e) By abduction and lateral displacement of the lower leg the joint-space can usually be inspected as far as the cruciate ligaments The free margin of the capsule is raised with an elevator and pushed out of the joint In some cases a portion of the vastus medialis lies in the intercondylar notch If this muscle cannot be pushed out it is excised One or both cruciate ligaments may be torn Reduction is easy when the interposed capsule and muscle have been levered out of the joint Capsule and medial collateral ligament are drawn over the medial

2252 a—c

Figs 2252 a—c—Lateral dislocation of left knee with a deeply drawn in transverse fold of the skin at the medial side of the tibial head This is a sign that the medial collateral ligament and the joint capsule have been avulsed from the medial condyle of the femur and included in the joint space Sustained by a 58 year old man who fell from a train

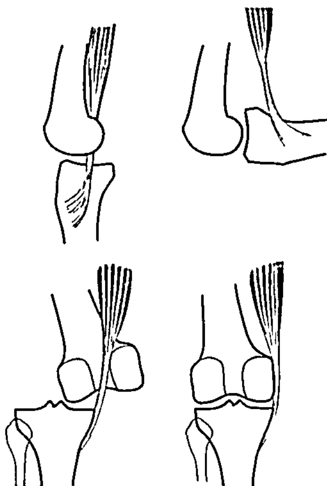


2252 d 2252 e

Figs 2252 d e—After severance of the skin at the knee of figs 2252 a—c the medial condyle of the femur lies free since the medial collateral ligament and the capsule are avulsed at the femoral epicondyle and included in the joint space They cover the medial condyle of the tibia Reduction becomes possible only if they are drawn out of the joint and restored to their proper place

Immobilization If the X-rays show good position, a plaster cylinder, as described on p 1515, is applied from the ankle to the hip joint over an anteriorly placed cord and with the knee at 170° (figs 2175—2177)

Second X-ray Control After application of the plaster cylinder new anteroposterior and lateral X-rays are taken, since slight displacement often occurs on application of the plaster cast



2249—2252

FIGS 2249 2250 —In lateral dislocations of the knee the tendons of the hamstring muscles lie in the intercondylar notch and make reduction of the extended knee impossible

FIGS 2251 2252 —If the knee joint is flexed to a right angle or more the tendons slip out of the intercondylar notch and reduction is then easy by traction and lateral pressure

Splitting the Plaster Cast To avoid circulatory disturbances the plaster cylinder must be split at once over the enclosed cord, throughout the whole length of the cast and through the last thread

Placing the Leg The leg is elevated on a splint

Application of the Walking Plaster If the swelling of the joint has subsided after 8—10 days, and the wound in case of operative reduction has healed, the split plaster cylinder is removed An Unna s paste dressing is then applied to the foot and a new plaster cylinder to the leg extending from the ankle

OPEN DISLOCATIONS OF THE KNEE JOINT

Origin They are mostly seen in motorcycle or automobile accidents when the tibial head strikes an obstacle with the knee flexed to a right angle Often the patella is comminuted and the tibial plateau (fig 2257) or a condyle of the femur (figs 2262 a—d) fractured

Treatment In open dislocations of the knee with rupture or thrombosis of the popliteal artery amputation should usually be done at once through the thigh If the vessels are intact, the wounds are excised according to the principles laid down in Vol I/pp 142—174 Torn muscles and ligaments are not sutured, so that no foreign bodies are buried Only the torn nerves should be sutured If, during wound excision, one detects a meniscus partly detached at its base (complete detachment of the meniscus is very rare) but not torn, the meniscus *should not be excised* but fixed at its attachment with 2 or 3 sutures After insertion of one or more rubber drains, the skin, and the skin only, is sutured Thus the open dislocation is changed into a closed one and is then treated as such The drains should be removed after 24 hours Severely displaced fragments of the tibial head or femoral condyles are reattached with screws (fig 2262 b)

Questions We Should Ask Ourselves When Treating Dislocations of the Knee to Avoid Failures

1 Have I, in patients in shock, treated the shock by application of warmth and local anesthesia (see Vol II/p 1089) before the reduction?
2 Have I inspected the shape and color of the leg? Have I tested active motion of the toes and ankle joints, sensation, and the pulses at the dorsum of the foot and behind the medial malleolus?
3 Have I looked for a transverse, deeply drawn-in groove at the level of the medial joint space?
4 Have I reduced the dislocation early by traction on the lower leg with the knee flexed, not extended or hyperextended?
5 Have I tested the pulse at the dorsum of the foot and behind the medial malleolus in patients whose pulse was not palpable before reduction?
6 Have I attempted suture of the vessel in rupture of the popliteal artery?
7 Have I upon failure of the vessel suture amputated as soon as the zone of demarcation was evident?
8 Have I tested the firmness of the collateral and cruciate ligaments after reduction?
9 Have I at once exposed the joint and removed the obstruction, in case of interposition of the capsule (recognizable by the transverse groove of skin at the medial side of the tibial head)
10 Have I thoroughly excised the wound in open dislocations?
11 Have I sutured torn nerves?
12 Have I removed the comminuted patella in open fractures?
13 Have I in open fractures reattached severely displaced fragments with screws?

up to the hip joint with the knee at a flexion of 170° This plaster cast is not split

Third X-ray Control After setting of the plaster cylinder new antero posterior and lateral X-rays are taken to make certain that reduction is complete and the knee is not overextended but flexed at least 10°

Exercises During the necessary period of immobilization the patient should use his leg as much as possible As soon as he is without pain, i e, after a few days, he starts walking In the first week he should walk at least 1 km daily This distance should not be covered all at once but distributed over the whole day Each following week he should increase the daily distance by 1 km, *if this causes no pain* To strengthen the quadriceps the leg should be regularly lifted to the horizontal position several times a day All other joints and muscles of the body should be exercised as well Appropriate work should be started soon

Period of Immobilization The plaster cylinder should be retained for 16 weeks *uninterruptedly* If it is discarded earlier, the ligaments have not yet united firmly enough, and the joint remains loose

Fourth X-ray Control After removal of the plaster cylinder new antero posterior and lateral X-rays are made to determine the position of the joint surfaces, to discover any ossification of muscles and ligaments, and to test the density of the bones

Further Treatment After the X rays the stability of the ligaments is tested and the range of motion of the joint measured An Unna s paste dressing is then applied from the web of the toes to the knee and an elastic bandage is wound around the knee The elastic bandage is removed at night Active flexion and extension is carried out on the knee support (Vol II/figs 1574, 1575) Exercises on the mountaineering apparatus may be started later on (see Vol II/pp 1205, 1206 and Vol I/figs 21, 22)

The patients are warned against massage and passive movements, since they both irritate and loosen the joint Massage must be strictly avoided in cases of thrombosis in view of the danger of embolism, 6 to 8 weeks after removal of the plaster cylinder the joint is, as a rule, stable and some cases will later achieve a full range of motion The swelling of the joint disappears all the more quickly the less forceful and painful movements are carried out

Unsuitable Methods of Treatment 1 Some recommend the application of *extension* after reduction This can only cause harm, as the torn ligaments are still further stretched

2 *Massage and passive movements without immobilization* This treatment is often recommended but surgeons using it report that loose, unstable joints develop in most cases and that their patients have to wear braces permanently

3 *Too short a period of immobilization* The joint will not become stable if immobilization is maintained too short a time especially when followed by vigorous physiotherapy

4 *Too long a period of immobilization* If as suggested by some authors the joint is immobilized 6—12 months it will become stable but mobility of the knee will be seriously limited

19 Has an Unna's paste dressing been applied to the foot, and a plaster cylinder to the leg, when the swelling has subsided, i e, 8—10 days after reduction?



Figs 2257 2258—X rays re figs 2253 2254 The lower leg is subluxated backwards and outwards and inwardly rotated (shown by the wide interosseous space between the tibia and fibula) The medial tibial condyle is depressed A flake of bone has been broken off the lateral tibial condyle



Fig 2259 2260—Check X rays re figs 2257 2258 after three months Fragments have healed in good position There is a bony shadow over the intercondylar eminence at the attachment of the posterior cruciate ligament

Figs 2261 2262—Check X rays re figs 2259 2260 after seven and a half years The X ray was taken in slight internal rotation (shown by the medial displacement of the patella and by the wide interosseous space between the tibia and fibula) Thus the normal valgus position seems to be missing Arthrotic changes are visible in the medial joint space but they cause no complaints Full range of active motion of the joint

14 Have I taken X-rays in both planes after reduction and after examining the firmness of the ligaments?
15 Have I, after X-ray, applied a plaster cylinder with a flexion angle of 170°, and not in extension or even hyperextension?
16 Have I taken new anteroposterior and lateral X-rays after application of the plaster cylinder to confirm that the joint has been completely reduced and not overextended?
17 Have I, after the second X ray control, *split the plaster cylinder through out its full length down to the last thread,* to avoid circulatory disturbances?
18 Has the leg been elevated on an oblique splint?



2253 May 22 1928

FIGS 2253 2254—Open dislocation of the right knee joint backwards and outwards in a girl of 17 caused by an automobile accident There is a 12 cm long gaping wound in the popliteal space extending into the joint The lateral head of the gastrocnemius the capsule of the joint and the origin of the posterior cruciate ligament are torn



2254 May 22 1928



2255 Aug 17 1928 2256

FIGS 2255 2256—Comparison photographs re figs 2253 2254 three months later The wound was excised the skin alone sutured and a plaster cast applied for eight weeks Wound healed without complications Three months after injury the knee could be fully extended and bent until the heel was only a hand s breadth from the buttock No abnormal lateral mobility but the head of the tibia can be moved backwards evidence that the posterior cruciate ligament has not quite united On removal of the cast the head of the tibia could not be pushed back The laxity occurred because the knee was not immobilized long enough

eighteen months to nine years after the accident He compared the pre-reduction with the re examination X-rays and photographs of all these patients and concluded that the ends results with reference to motion and stability of the joint were good, if proper treatment had been applied

Motion Of the 10 cases, one leg had to be amputated due to rupture of the popliteal vessels Another patient sustained a double fracture of the femur Due to this, range of motion was limited A third patient was not admitted until 14 days after the injury and reduction was thus delayed His range of motion was 180° to 100° (Vol I/figs 49—51) In all other cases with immediate reduction the range of motion was at least 180° to 60°, in three cases full range of active motion was achieved



2262 c May 29 1954 2262 d

Figs 2262 c d—Photographs re figs 2262 a b taken on admission obliquely from in front and from laterally The knee joint is torn transversely in front The lateral condyle of the femur is broken off comminuted and displaced far laterally and dorsally The patella is fractured transversely and split longitudinally

Stability With the knee extended all cases showed lateral and antero-posterior stability At a flexion angle of 150° three cases had a slight laxity of the joint At a flexion angle of 110° there was a slight drawer sign in three patients These three had been immobilized with the knee extended or over-extended, instead of being flexed at an angle of 170°

Impairment of motion and of firmness were found only in patients who had been immobilized for less than 12 weeks

All patients had strong muscles, had resumed their former occupation and could practice sports They were free from complaints

Myositis ossificans occurred only in the patient whose dislocation was reduced after fourteen days (Vol I/figs 49—51)

Slight *ossification of ligaments* was seen in two cases They had no limitation of motion

Arthrotic changes developed in one case with intraarticular fracture of the tibial head They caused no pain (figs 2261, 2262)

20 Have I taken anterior and lateral X-rays after application of the Unna's paste dressing and the plaster cylinder, to see whether the reduction is complete and the knee is flexed at 170°?
21 Has the patient, after application of the Unna's paste dressing and the plaster cylinder, taken up regular walking exercises? Does he actively raise his leg, does he exercise the rest of the body?
22 Has the patient been provided with satisfactory work?
23 Has the plaster cylinder been retained for 16 weeks to avoid an unstable joint?
24 Have I tested the firmness of the ligaments after removal of the plaster cast?



Fig 2262 a—Incomplete *open* fracture dislocation of left knee joint The tibia is subluxated outwards and backwards the lateral condyle of the femur is shorn off and comminuted the patella is fractured The soft parts are widely torn open Sustained in a motorcycle accident Careful excision of wound cleaning of the bones excision of the soiled patella fixation of the femoral fragments with screws

Fig 2262 b—Check X ray re fig 2262 a two months later The wound has healed without complication Good apposition of the fragments The patella is absent

25 Have I measured and recorded the range of motion of the knee?
26 Have I avoided massage and passive motion which irritate and loosen the joint?
27 Have I omitted exercises which cause pain (see Vol I/p 45)?
28 Have I taken X-rays on completion of treatment to determine the density of bones, the apposition of the joint ends and the presence of ossification of muscles and ligaments?

End-Results of Dislocations of the Knee Joint

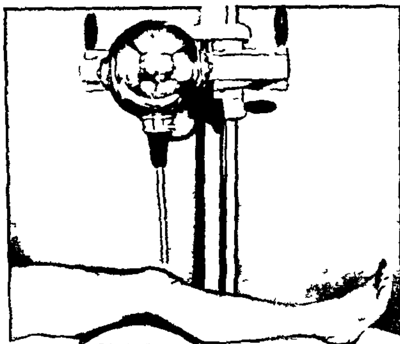
Kromer[1] reviewed our first ten cases of dislocation of the knee of the years 1927 to 1934 He re examined the patients clinically and radiologically

[1] Kromer Behandlung und Ergebnisse der traumatischen Kniegelenksverrenkungen Ergebnisse der Chirurgie und Orthopadie *29 583—626 1936*

Contusion of the knee occurs when the joint becomes wedged between two objects either with considerable force or speed

Origin of a Bruised Knee The causes are a fall on the knee, striking the knee against an obstacle, or the impact of light or heavy objects

Origin of a Knee Contusion In a standing or moving individual the joint becomes wedged between two objects, or the knee of a reclining person is hit by a falling object, or else it is run over by a vehicle In bruises as well as in contusions the violence acts transversely or obliquely to the long axis of the joint



April 24 1938

Fig 2263 —Radiography of the knee in slight flexion To standardize flexion a wedge of limewood shaped to the popliteal region is placed under the knee It is 45 mm high 18 cm long and 13 cm wide Since the articular surface of the tibial head slopes dorsally the central ray should hit the knee in a dorsocaudal direction under an angle of 5° to 10° For pneumoradiography the X ray film is placed on the wooden wedge without using a cassette

Pathology Anatomical changes vary according to the severity of the violence and the shape of the object producing it Abrasions and superficial extravasation of blood are frequent Sometimes the skin is avulsed from the underlying tissue and may later become necrotic Great violence may cause rupture of deep vessels followed by effusion of blood into the joint As the synovial membrane usually remains intact, such an effusion is often much larger and firmer than in ruptures of the collateral ligaments and bone fractures, because the blood cannot be reabsorbed as quickly

Diagnosis As a rule this is easy as the patient s history will reveal a typical mechanism of injury Bone fractures and ruptures of ligaments must be exclused by appropriate examination (see p 1509) There is spontaneous *pain* as well as pain on motion and especially on local pressure After slight violence it will be mild and will disappear quickly, after greater violence

Ender re examined our 22 dislocations of the knee treated between 1935 and 1947, and five of the seven survivors of Kromer's cases In the six years from 1948 to 1953, 21 more dislocations of the knee were treated, but not yet re-examined

Deaths Of the 22 patients with dislocations of the knee surveyed by Ender, two died on the day of accident due to severe concomitant injuries Of the survivors, 14 were treated conservatively and 6 irreducible dislocations were treated operatively Among the six operative cases three were delayed

14 Cases Treated Conservatively Motion Of the 14 patients treated conservatively 12 were re examined Three of them had full range of active motion Seven patients had full extension, but flexion was limited by 10° to 20° The worst result had a range of motion from 180° to 100°

In the five cases from Kromer's original series the range of motion had become somewhat more restricted after a follow up period of 16 to 24 years

Lateral Stability In extension, ten of twelve patients had firm collateral ligaments, only two showed slight laxity

Drawer Sign Among the twelve cases the drawer sign was positive in four, but not enough to require operation

Arthrotic Changes Of the 14 cases only one case showed slight arthrotic changes He also had a fracture of the tibial head

Among the seven cases of Kromer's, three had slight arthrotic changes after 16 to 24 years whereas such changes were present at the first re examination in only one

Slight ossification of the ligaments were found in 7 of the 14 cases

Ossification of the muscles did not develop

Three Cases Treated by Early Operation Motion The two re examined patients had full extension, their flexion was limited by 10° to 20° Both patients showed lateral stability of the knee but the drawer sign was slightly positive

Three Cases Treated by Late Operation, Two of Which Were Re-examined Motion The range of motion was from 180° to 100° in one case 160° to 150° in the other case with extensive ossification of muscles and ligaments

This shows that good end results can generally be expected by proper treatment instituted early, but in patients whose treatment has been delayed, results are far less satisfactory

79 BRUISES AND CONTUSIONS OF THE KNEE (CONTUSIO GENUS)

Bruises are minor injuries of the knee but there are also severe contusions Sprains of the knee are, as a rule slight injuries Dislocation of the knee is always a severe injury and still more severe is rupture of the joint

Bruises are caused by direct exterior violence They are sustained either when a person is standing or moving In these injuries there is no severe damage to ligaments, no dislocation and no bone fracture, nor is the joint perforated

capsule, especially if combined with continual application of excessive heat Forceful passive movements may cause permanent limitation of joint motion With these methods the skin becomes marbled, and the bones develop a mottled atrophy which is not seen if the knee joint is not irritated

IMPACTION OF THE KNEE (COMMOTIO GENUS)

Impaction of the knee results from a vertical fall on the feet with the knee joint fully extended, i e, by a violence acting in the longitudinal axis of the limb, the articular surfaces being rammed together with great force Breaks in the cartilage and effusion of blood may occur Great violence causes the typical depressed fractures of the tibial head

Treatment is carried out as for contusions or bruises of the knee

80 SPRAIN (DISTORSIO) AND RUPTURE (RUPTURA) OF THE MEDIAL COLLATERAL LIGAMENT OF THE KNEE

Origin Injuries of the medial collateral ligament frequently occur indirectly, by abduction and external rotation of the lower leg with the knee slightly flexed, e g, in skiing, in a jump downward and in other situations in which the lower leg is angulated outwards This injury equally often results from direct violence against the outer side of the knee

Site of the Injury The medial collateral ligament is far more vulnerable to injury than the lateral one, since it is exposed to much greater strain due to the normal valgus position of the knee Similar conditions exist at the elbow where medial dislocations with rupture of the collateral ligament are exceptional The medial collateral ligament may rupture at its upper attachment, in the middle, or at its lower attachment (figs 2284 a—f, 2301—2304) In rare cases the ligamentous insertion is avulsed with a piece of bone (figs 2279 to 2281, 2284 a) This injury is rare The lateral collateral ligament tears at the upper end (fig 2301), sometimes at the lower end with avulsion of the tip of the fibular head (figs 2373 a—c), or at the attachment of the fascia lata

Types of Injury Depending on the amount of violence, injuries of the medial collateral ligament will be major or minor We differentiate four degrees of this injury, namely

1 Sprain of the medial collateral ligament
2 Stretching of the medial collateral ligament
3 Complete tear of the medial collateral ligament
4 Complete tear of the medial collateral ligament with simultaneous rupture of one or both cruciate ligaments and the posterior portion of the capsule with its ligamentous reinforcements

Diagnosis Accurate recognition of the degree of injury is exceedingly important since proper treatment depends on it

In the *first degree of the injury*, sprain of the collateral ligament, the patients feel a sudden pain at the medial side of the knee When sustained in skiing the patients can usually continue skiing In general football players

it will be severe and lasting Considerable pain may appear in taut joint effusions

Superficial or deep abrasions of the skin and extravasation of blood are frequent In severe contusions circumscribed areas of the skin may be pale and anemic After a few hours these areas become dry and brown

After slight violence *mobility and usability* are only slightly impaired After severe violence and with large joint effusions walking is painful or impossible Mobility is considerably reduced

Complications Following Knee Bruises and Contusions If massage, passive movements and excessive heat are avoided, these injuries usually heal without complications and within a short period of time

Treatment In minor injuries an elastic bandage is applied The initial pain is quickly relieved by cold compresses In severe swelling and large effusions of the joint, the leg is elevated on a Braun splint or pillow and treated with wet compresses, if the skin is intact After 2—3 days a pressure bandage is applied with foam rubber If tension pain develops due to the effusion the skin is anesthetized locally with a fine gauge needle and the joint then aspirated with a heavy-gauge needle Then a pressure bandage is applied over foam rubber, so that the effusion cannot recur The pressure bandage must never produce pain

Treatment of Skin Disturbances If, in deep abrasions, sand or dirt particles are embedded in the skin, they should be scraped away with the scalpel under local or a brief general anesthesia A sponge with balsam of Peru is applied The superficial wound will be covered with epithelium after 5 to 6 days If this thorough cleaning of the skin is omitted, dirty wounds which take a long time to heal will result Antitetanus serum is given if the patient has not previously been actively immunized against tetanus

If in severe contusions of the knee, the skin is avulsed from the underlying tissue and becomes gangrenous, it should be excised before its margins become moist The defect should be covered with a split thickness skin graft If the necrotic skin has already become moist, formation of clean granulations must be awaited Then secondary skin grafting may be carried out with a split graft or pinch grafts

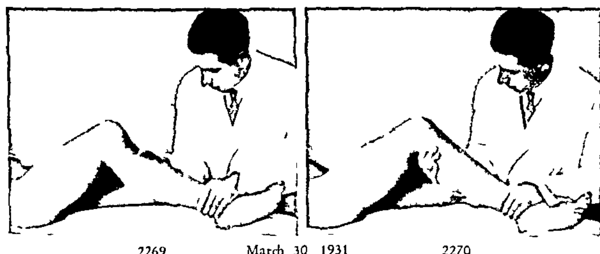
Further Treatment As soon as the swelling and severe pain have disappeared, an Unna s paste dressing is applied from the web of the toes to the knee An elastic bandage is wound around the knee which is removed at night In slight bruises this treatment can be begun on the first day A plaster cast should be applied only after skin grafting, in other cases it proves harmful since it prolongs the period of treatment Diathermy is appreciated by the patients and may speed up the healing process

Duration of Treatment According to the severity of the injury the complaints will subside in a few days to several weeks Some surgeons maintain that after blood effusion into the knee joint permanent disability will remain in 25 per cent of the cases In our experience complete recovery is the rule

Unsuitable Methods of Treatment Heat must not be used in the first days since it will increase hemorrhage into the joint The joint must not be irritated by massage and passive movements, since this will lead to thickening of the

with a flexed knee which is held stiff with the foot placed normally, or on tiptoe On attempting to abduct the lower leg, a severe pain is produced on the medial side of the knee cranial to the joint space (fig 2167) The joint is stable and even in flexion lateral laxity is absent There is a distinctly localized tenderness over the upper attachment of the medial collateral ligament ("skier s point"), whereas the joint space is not tender Walking downhill causes pain The X-ray is negative

In the *second degree of the injury, stretching of the collateral ligament,* the same symptoms and signs are observed as in sprains, namely, increasing pain, increasing limitation of extension, pain on abduction medially and tenderness over the femoral attachment of the medial collateral ligament The difference is that, after a few hours, swelling occurs at the femoral attachment of the



2269 March 30 1931 2270

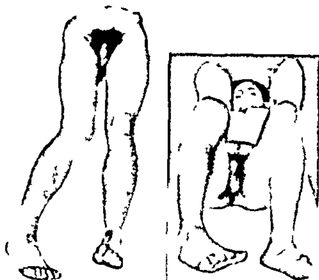
Figs 2269 2270 —Comparison pictures re figs 2264—2268 before application of the plaster cast Slight pressure on the front surface of the head of the tibia displaces the head of the bone backwards indicating that the posterior cruciate ligament has been torn Pressure on the calf from behind restores the tibia to normal position Treatment plaster cylinder for 16 weeks at a flexion angle of 165°

ligament and blood effusion sometimes occurs in the joint In some cases there is a slight lateral laxity, not with the knee extended, but with a flexion angle less than 170° External rotation in slight flexion produces pain, but causes no pain in a knee flexed to a right angle as the collateral ligament is then relaxed Walking downhill causes pain X-ray sometimes reveals a slight gaping of the medial joint-space if the knee is held in forced abduction

In the *third degree of the injury* rupture of the collateral ligament, the patient feels a sudden severe pain and can walk only with difficulty When the injured leg bears the weight the patient has a sensation as if the femur were going to slip inwards past the tibia Usually the medial aspect of the joint swells quickly but not severely There is no loss of full extension as in the first and second degree of the injury, since the reflex muscle spasm caused by pain is absent after complete severance of the ligament Pain at the medial side on abduction is present but is less pronounced than in first and second degree injuries Tenderness is found equally often in the lower (figs 2284 c, d, 2302—2304) as in the upper (figs 2284 a, b, e, f, 2301) half of the ligament Examina-

also continue play The pain increases after some hours and that night sleep is disturbed

On examination swelling or an extravasation of blood are absent At first the knee can be fully flexed and extended When the pain increases, extension will be limited by 10° to 20° due to reflex muscle spasm The patients then walk



2264 March 30 1931 2265



2266 March 30 1931 2267 2268 April 6 1933

Figs 2264 2265 —Rupture of the medial collateral ligament and the posterior cruciate ligament Sustained by a 26 year old laborer in jumping from a street car Severe abduction and internal rotation of the lower leg In flexion and inward rotation the tibial head sinks backwards and outwards a sign that the posterior cruciate ligament is torn

Fig 2266 —X ray re fig 2264 in normal position of the lower leg Joint space normal A small piece of bone can be seen between the medial and lateral tubercles of the intercondylar eminence which corresponds to the insertion of the posterior cruciate ligament

Fig 2267 —Check X ray *re fig 2266 under local anesthesia in forced abduction The joint* space gapes 3 cm on the inner side

Fig 2268 —Check X ray re figs 2266 2267 two years later A small round bone shadow is visible cranial to the medial joint space Full range of motion The joint is stable in extension Slight lateral laxity at the medial side in flexion No posterior drawer sign Asymptomatic

ligament injury remains undamaged as a rule since the joint is not compressed but opened However, separation of the meniscus from the collateral ligament occurs often (figs 2284 a—f, 2301—2304)

X-ray Examination of the Injuries to the Collateral Ligaments Routine X rays will show a positive finding only if a bony attachment of the collateral or cruciate ligament has been avulsed as in figs 2271—2278, 2315—2320 and 2373 The true picture of the extent of the rupture of collateral ligament is shown if *X-rays* are taken *under abduction strain,* with the knee at a flexion angle of 160° to 170° To standardize the examination we place a linden wood



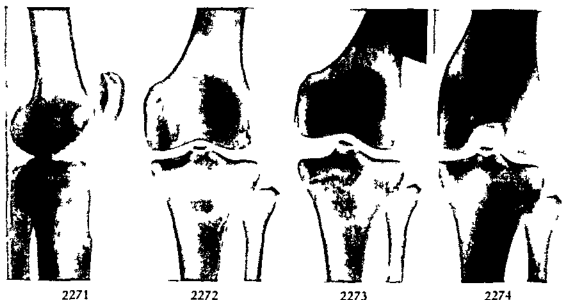
Figs 2275 2276 —Check X rays re figs 2271—2274 in plaster The lateral view shows the joint at 170° flexion In the anterior view the inner joint space is again closed and has the normal height of 5 mm

Figs 2277 2278 —Check X rays re figs 2271—2276 six months later There is lateral stability even under abduction strain No ossification of the collateral ligament, no arthrotic changes normal density Bony union of the tibial spine incomplete The joint was immobilized over a period of 14 weeks There is lateral and anteroposterior stability and full range of active motion No swelling

wedge underneath the knee This wedge is 45 mm high, 18 cm long and 13 cm wide, it is transparent to X-ray If abduction is painful, the medial side of the joint is locally anesthetized to eliminate reflex muscle spasm on abduction Local anesthesia may only be applied on the first day after the injury On the second or third day X-rays under strain may be taken only without anesthesia, after the third day they must be omitted altogether, since beginning adhesions may become loosened and the joint thus damaged Under the same conditions anterior and lateral comparison x-rays are taken of the sound knee Forced abduction can also be obtained by tying both femurs together proximally to the knee joint and by pushing sand bags between the ankle joints With this arrangement both anteroposterior pictures can be taken at the same time for good comparison For the anteroposterior picture the

tion for pain on abduction in slight flexion reveals a slight gaping at the medial side of the joint The condyles knock against each other when the joint is again adducted In full extension or hyperextension the joint is laterally fairly stable Marked lateral gaping in extension in a rupture of the collateral ligament can be produced only when the cruciate ligament has been torn as well X rays show gaping at the medial side of the joint, if it is held in forced abduction (figs 2302—2304)

In the *fourth degree of the injury* rupture of the medial collateral ligament with simultaneous rupture of one or both cruciate ligaments and the posterior



2271 2272 2273 2274
December 18 1937

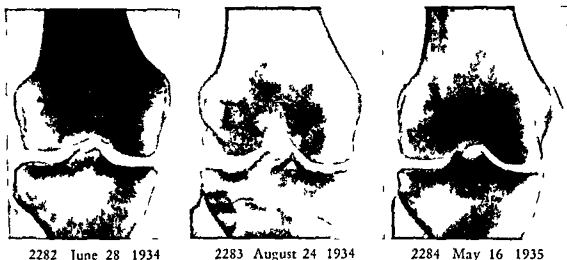
Figs 2271 2272 —X rays of an injury to the left knee joint with marked effusion of blood and inability to walk Sustained by a 54 year old man who was hit on the lateral side of his knee by a heavy sack The usual X ray shows no more than an avulsed tibial spine

Fig 2273 —Check X ray re fig 2272 taken in forced abduction The medial side of the joint space can be opened to 16 mm sign of a ruptured collateral ligament The avulsed portion of the tibial spine is drawn upwards Lateral subluxation of the tibia

Fig 2274 —Check X ray re fig 2272 at a flexion angle of 140° The posterior portion of the intercondyloid fossa is shown With this X ray technique bony avulsions from the femoral attachments of the cruciate ligaments and their ossification can be demonstrated (see Vol I/fig 51)

portion of the capsule the sudden pain is especially severe The patient can no longer bear weight on the injured leg Marked swelling and effusion of blood into the joint develop quickly Little pain is felt on abduction The medial joint space can be opened not only with the knee flexed but also with it extended or hyperextended Moreover with the knee flexed, the tibia can be displaced on the femur in the anteroposterior plane, i e anteriorly in rupture of the anterior cruciate ligament and posteriorly in rupture of the posterior cruciate ligament (figs 2269—2270) Anterior plus posterior displacement can be elicited in rupture of both cruciate ligaments (figs 2284 g—m) There is tenderness over the whole medial and posterior side of the joint The X-ray often reveals bony avulsions from the tibial attachment of the anterior or posterior cruciate ligaments *The meniscus in all four degrees of collateral*

re-applied as soon as it becomes loose, i e, every one to three weeks It usually takes four to six weeks before full extension is regained During this time hot air, diathermy and wet compresses may be used with moderation These are appreciated by the patient but do not much shorten the period of recovery The joint should be kept warm especially in winter Overheating is harmful, especially if the patients must go out of doors after the treatment Frequent overheating of the joint leads to a marbled discoloration of the skin due to vascular damage Thickening of the soft tissues, ossification of the ligamentous



2282 June 28 1934 2283 August 24 1934 2284 May 16 1935

Fig 2282—Knee joint of a 37 year old female who was knocked down by an automobile four weeks previously Thereupon had pain in the right knee and swelling She received daily energetic massage and passive movements No X ray findings apart from slight atrophy of bones The medial side of the knee was slightly loose Range of motion 170° to 135°

Fig 2283—Check X ray re fig 2282 eight weeks later Since mobility had not improved, the knee joint had been manipulated under general anesthesia by a surgeon six weeks previously Severe pain and swelling followed Thereupon daily hot air diathermy, massage and passive movements which caused much pain The knee is now severely swollen and the skin marbled Motion 160° to 140° Extensive calcification at the femoral attachment of the medial collateral ligament

Fig 2284—Check X ray re fig 2282 after eleven months The calcification at the femoral attachment of the medial collateral ligament has become smaller but more dense The swelling has disappeared Motion 180° to 110°

attachments, spotty bone atrophy and prolonged limitation of motion will follow

To follow the progress during treatment, the range of motion is measured weekly with a goniometer and recorded in the case history

Limitation of extension disappears as soon as the joint is anesthetized locally by Novocain or refrigeration However, it re-appears when the anesthetic wears off Repeated injections, which are often recommended, will not much shorten the period of treatment Pain will generally subside sooner with the use of diathermy

Powerful massage and passive movements are always harmful and prolong the period of recovery If they are carried out energetically ossification of the collateral ligament (Stieda-Pellegrini s shadow), severe decalcification and permanent impairment of motion will follow Figures 2282—2284 show how the

central X-ray should point posteriorly and distally (fig 2263) since the articular surface of the tibial head declines dorsally Only then can the joint space be seen well

X-rays after *injection of air into the joint* (pneumoarthrography) serve to differentiate tears of the proximal (fig 2301) and the distal portions (figs 2302—2304) Usually one can also demonstrate that the meniscus has remained intact

Complications after Injuries of the Collateral Ligaments If strained or stretched collateral ligaments are treated too vigorously, persistent flexion



2279 September 28 1934 2280 September 28 1934 2281 November 26 1934

FIG 2279—Avulsion of the femoral attachment of the medial collateral ligament sustained by a 21 year old gardener who fell with his motorcycle

FIG 2280—Check X ray re fig 2279 under abduction strain The avulsed piece of bone is pulled distally The medial joint space gapes 16 mm

FIG 2281—Check X ray re figs 2279 2280 eight weeks later Bony union of the avulsed attachement of the ligament Somewhat decreased density of the bones Was treated with Unna s paste dressing and plaster cylinder for eight weeks Two weeks after removal of the plaster the knee had full range of active motion The joint was stable

contractures may ensue Complete tears of the collateral ligament with or without rupture of the cruciate ligaments will lead to a loose joint and sometimes to arthrotic changes if proper treatment is not carried out Ossification of the medial collateral ligament (Stieda-Pellegrini s shadow, figs 2283, 2284) may develop

Avoidance of Complications after Injuries of the Collateral Ligaments Complications can be avoided if pain stimuli causing reflex muscle spasm are abolished in the first and second degree injuries, and if in the third and fourth degree injuries, with or without operation, immobilization is maintained until the ligaments have firmly united

Conservative Treatment of the Injuries of the Medial Collateral Ligaments

In *first degree injuries* sprains of the collateral ligament, the pain will quickly subside if an Unna s paste dressing is applied from the web of the toes to the knee and an elastic bandage wound around the knee Walking including going downhill, will at once be improved The Unna s paste dressing is

In old cases a sand bag may be placed underneath the heel for 15—30 minutes daily, and a second sand bag on the knee in order to slowly straighten the knee *without causing pain* If this fails, extension by means of a foot sling weighted with 2—3 kg may be exerted overnight (Vol II/fig 1702)

In third degree injury, rupture of the collateral ligament, proper healing can only take place if the joint has been immobilized in good position by a plaster cylinder over a long enough period, i e until the ruptured ligament has firmly united Immobilization should be started as early as possible so that the torn portions of the ligament do not retract



2284 d—f

FIG 2284 d—Rupture of the medial collateral ligament at its tibial end with rupture of the upper attachment of the meniscus

FIG 2284 e—Stretching and fraying of the medial collateral ligament with detachment of the meniscus at its upper and lower attachments In such a case the collateral ligament and the meniscus heal within 10 to 12 weeks if proper immobilization is applied

FIG 2284 f—Stretching of the medial collateral ligament and detachment of the meniscus at its upper margin Figs 2284 a—f are taken from Ivar Palmer s paper [1]

The best results are obtained if the plaster cylinder is applied within the first 2—3 days But even after eight days results are usually good If the plaster cylinder is not applied until the second week the joint will usually not become stable Immobilization beginning two weeks after the injury is usually unsuccessful As the swelling rarely is severe the plaster cylinder may be applied as early as the first or second day at a flexion angle of 170° (for technique see p 1515 and figs 2175—2177) If the cast is applied in extension or hyperextension the ligament becomes too long (figs 2171—2174) and lateral laxity will remain This will damage the joint rather than improve it Therefore the position of the joint in the cast must be established by X-rays in both planes (figs 2275 2276) To avoid swelling of the foot an Unna s paste dressing is applied previously The plaster cylinder must be split at once, to avoid circulatory disturbances and pain

[1] Palmer 1938 *Acta chir scand Vol XCI Part I—IV*

period of treatment is unduly prolonged and the joint permanently damaged by forceful measures such as manipulation under general anesthesia, massage and passive motion In our cases, where massage and passive motion have always been omitted, Stieda-Pellegrini s shadow has been found only exceptionally, whereas some authors report its occurrence in 25% of their cases

If in the second *degree injury*, stretching of the collateral ligament, swelling and pain are severe, the patient is kept in bed for some days The leg is elevated on a Braun splint or a pillow The foot is suspended by an Unna's paste sling (see Vol II/p 1196) or triangular bandage (fig 2641) Wet com



2284 a—c

Fig 2284 a—Avulsion of the femoral attachment of the medial collateral ligament as in figs 2279—2281 with separation of the proximal portion of the attachment of the meniscus

Fig 2284 b—Rupture of the medial collateral ligament at the proximal end (without bony *avulsion) with separation of the proximal portion of the attachment of the meniscus*

Fig 2284 c—Rupture of the medial collateral ligament near its tibial end The torn portion is included in the joint space The attachment of the meniscus is severed distally Ehalt observed patients with rupture of the femoral portion of the ligament and inclusion in the joint space proximally to the meniscus

presses are periodically applied to the knee Hot air must not be used in the presence of a blood effusion as it may increase After some days an Unna s paste dressing is applied from the web of the toes to the knee and an elastic bandage is wound around the knee Further treatment is the same as in strains of the collateral ligament (see p 1570) Full extension will be regained within four to six weeks The slight lateral laxity can usually no longer be elicited after this time

In the strained as well as the stretched collateral ligament forcible extension of the joint under general anesthesia and subsequent application of a plaster cast are superfluous and harmful since full extension will always be regained with proper treatment Besides, forcible extension is a frequent cause of ligamentous ossification The duration of treatment will always be prolonged by these methods

alone Method and period of immobilization, and exercises are carried out as in third degree injuries of the collateral ligament (see p 1573)

End-results of Rupture of the Collateral Ligaments We have treated more than one thousand cases with or without involvement of the cruciate ligaments in this way Most cases were stable in extension In flexion some cases showed slight lateral laxity In spite of the long immobilization the knee joint became freely mobile in most cases Most patients resumed their occupation and sports For example a 37 year old physician who, while skiing, sustained a rupture of the collateral ligament with gaping of the joint space for 18 mm, climbed Montblanc six months later

81 SPRAIN (DISTORSIO) AND RUPTURE (RUPTURA) OF THE LATERAL COLLATERAL LIGAMENT OF THE KNEE

As has been mentioned on page 1565, injuries of the lateral collateral ligament of the knee are much less common than those of the medial

Origin They usually result from indirect force by adduction of the lower leg with or without concomitant torsion The peroneal nerve is sometimes also torn The avulsed tip of the fibula may be lodged in the joint space together with the collateral ligament and parts of the joint capsule

Diagnosis This injury is evaluated in the same way as those of the medial collateral ligament

Conservative Treatment of Injuries to the Lateral Collateral Ligament

Conservative treatment of sprains and ruptures of the lateral collateral ligaments is carried out in the same way as for the medial except that it should only be performed where the gaping of the joint space does not exceed 25 mm If the joint space can be opened more than this, treatment should be operative as the lateral collateral ligament does not always unite by mere immobilization

Operative Treatment of Fresh Ruptures of the Medial Collateral Ligament of the Knee Joint

Many surgeons recommend operative treatment in ruptures of the medial collateral ligament in order to shorten the period of treatment and to obtain better stability of the joint In the year 1939 we carried out operative treatment in ten patients Jorg Bohler[1] re-examined these patients first three and one half and again thirteen years later For comparison he also re examined ten patients who had been treated conservatively in the same period Among the operatively treated patients he found extensive ligamentous ossification in four cases, severe muscular atrophy in most cases, and in some cases sensory disturbances in the region of the saphenous nerve which were disagreeable when kneeling Infection did not occur but this danger cannot be overlooked Among the patients treated conservatively there was no case of ligamentous ossification, saphenous nerve disturbances, or severe muscular atrophy

[1] Jorg Bohler Die operative Behandlung der frischen Seitenbandrisse des Kniegelenkes Arch orth u Unfall Chir *40* 93—102 1953

Change of the Plaster Cylinder After one week a new plaster cylinder is applied with a flexion angle of 170° At this time the joint must not be tested for lateral stability, since the fresh adhesions would be disturbed and firm union rendered impossible

Application of a Shoulder Strap If the plaster cylinder slips downwards a strap is passed over the shoulder of the other side as in Vol II/figs 1581, 1582

Exercises With the plaster cylinder the patients can at once get up and walk n the first week they should walk a distance of at least 1 km a day, not all at one time but distributed over the entire day The daily distance should be increased by 1 km each week Besides, the leg should be raised to the horizontal several times a day, *if this produces no pain* All other muscles of the body should be exercised as well

If the patient walks about with the plaster cylinder there is no danger of stiffening of the joint or quadriceps atrophy since the muscles are powerfully stimulated by walking The muscles are strengthened by the active raising of the leg weighted with the plaster, but not by massage The patella moves on the femur and will not become adherent The tensor articularis genu contracts with the quadriceps to unfold the suprapatellar pouch

The *period of immobilization* depends on the extent of the rupture of the collateral ligament This must therefore be accurately determined by X-rays under abduction strain and, if necessary, under local anesthesia (see p 1569) The width of the joint space in the A P X ray is normally 4 to 6 mm If the joint space can be opened up to 7 or 8 mm only an Unna s paste dressing is needed If the joint gapes 9 to 10 mm a plaster cylinder is applied for 6—8 weeks With a gaping of 10 to 15 mm immobilization is needed 9—10 weeks and with a gaping of 16 to 20 mm 12 weeks will be required If the gap is greater than this the plaster cylinder is left on for 16 weeks In the rare cases of avulsion of the bony attachment as in figs 2279—2281 and 2284 a, immobilization of 8 weeks will suffice when there is good apposition of the bony fragment

Since the application of a plaster cylinder for a period of from 8 to 16 weeks is a major intervention, this should only be carried out if the existence and the extent of rupture of the collateral ligament have been accurately determined by X-rays taken under strain

Further Treatment After removal of the plaster cylinder a new Unna s paste dressing is applied from the web of the toes to the knee and an elastic bandage is wound around the knee The patients are told not to flex the knee forcefully as it would swell and become hot If the patients have walked conscientiously with the plaster cylinder there will be little muscle atrophy On removal of the cast the knee can usually be flexed to an angle of 120° and after one week to 90° In young patients there is usually free range of motion after 3—4 weeks in old patients after 6—8 weeks The knee joint is usually stable in extension In flexion a slight lateral laxity is sometimes found

In fourth degree injury, rupture of the collateral ligament with simultaneous rupture of one or both cruciate ligaments and the posterior ligaments of the capsule, treatment is carried out as in rupture of the collateral ligament

necessary, if the patient's home conditions are satisfactory It can be carried out by every surgeon Moreover, there is no danger of infection or injury to the saphenous nerve Unfortunately neither we nor Ehalt have had time to re examine all our conservatively treated cases But we know that they rarely appear for re assessment of disability evaluation This suggests that as a rule no permanent disturbances follow conservative treatment of sufficiently long immobilization in flexion of 165° to 170° and regular exercises

Our Current Indication for Operation of Fresh Ruptures of the Medial Collateral Ligament At present patients in whom more than 10 days have elapsed since the accident, and in whom the joint space can be opened to more than 15 mm will be treated operatively In such cases the torn ligament will not unite in its former length in spite of long immobilization

Operative Treatment of Fresh Ruptures of the Lateral Collateral Ligament

Since, in the case of a ruptured lateral collateral ligament laxity of the joint sometimes remains if the joint space can be opened up to more than 25 mm , we prefer to suture it Simultaneous avulsion of the tip of the fibular head should be fixed by a wire loop (figs 2372 a—c) The technique of the wire suture is described on p 1694 We reported our first case in 1918 [1]

In peroneal nerve paralysis the nerve should be exposed Suture may be difficult since the nerve ends are usually frayed and have to be excised Flexion of the knee joint may be necessary to enable nerve suture

Delayed Conservative Treatment of Rupture of the Collateral Ligament of the Knee

This group includes those patients who first appear for treatment a few days to a few weeks after injury, but cannot yet be classified as "old ruptures "

The troubles caused by the slight laxity in ruptures of the collateral ligament seen late can be alleviated by elevating the inner border of the heel, applying an Unna's paste dressing or rubber stocking to the lower leg and an elastic bandage to the knee

Application of a plaster cylinder is useless in these cases as the ligament cannot unite in its former length and the joint cannot become stable Such measures are not only superfluous but even harmful

Operative Treatment of Old Ruptures of the Collateral Ligament of the Knee

According to Max Lange the simplest and best treatment is to expose the medial collateral ligament through a curved longitudinal incision, chisel off the femoral attachment, thread the piece of bone with strong silk and fix it 10 to 15 mm higher to a hole bored through the femur We fix the bony flake with a 10 mm wide staple of stainless steel A plaster cylinder is applied for eight weeks

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[1] Bohler Über einen Abrißbruch des Wadenbeinkopfchens Zentralbl f Chir *45* 100—101 1918

Lange Orthopadisch chirurgische Operationslehre Munchen Verlag Bergmann 1951 p 610—612

	Treatment	
	Operative	Conservative
Period of Treatment in Days	122 9	95 0
Hospitalization in Days	27 8	3 4

We have discontinued operative treatment in these cases, since the results were less satisfactory at that time, and the period of treatment longer than with conservative treatment

In 1952 and 1953 Ehalt[1] operated upon 106 cases and reported on the results of 50 cases Before operation he obtains X-rays of both knee joints in abduction strain under general anesthesia to determine the degree of gaping *and to recognize bony avulsions The operation is performed under a tourniquet* through a medial longitudinal incision The branches of the saphenous nerve are carefully preserved If the superficial layer of the ligament appears intact in spite of the fact that the joint space could be opened during the clinical and X-ray examination, it is split longitudinally The tear is then found in the deep layer (fig 2284 f) After exposure of the ligamentous tear the joint space is opened to recognize injuries to the menisci and cruciate ligaments If a portion of the capsule is included in the joint space as in fig 2284 c it is drawn out The torn portions of the ligament are accurately apposed and sutured with fine silk, Pehafil or Supramid Bony avulsions at the femoral attachment of the ligament or avulsion of the ligament from the femoral or tibial periosteum are fixed with a nail or staple Suture of the ligament is difficult if its torn ends are badly frayed During skin suture care must be taken not to include a saphenous nerve branch A plaster cylinder is applied at a flexion angle of 160° and after 3 weeks at 180° The total period of immobilization is six weeks

The difference between the present operative technique of Ehalt and our former technique is that the torn portions are apposed and retained in good position by fine sutures only The plaster cast serves to prevent redisplacement Formerly we aimed at obtaining a stable joint at operation by means of thick mattress sutures and reafing sutures The consequence of burying many heavy silk sutures was extensive ossification and scarred thickening of the ruptured collateral ligament Ehalt has observed only slight ossification of the ligament in 10% and Stieda-Pellegrini shadow in 8% of his cases In athletes under 40 years of age the results were very good, insured patients, however, who had an industrial accident frequently continued to have complaints

Ehalt s periods of treatment in the operatively treated cases were as follows

	Athletes	Insured Industrial Accidents
Total Period of Treatment in Days	79	106
Hospitalization in Days	24	28

The comparatively long duration of hospitalization in Ehalt s and Jorg Bohler s cases is surprising With conservative treatment no hospitalization is

[1] Ehalt, W Behandlungsergebnisse bei der Naht der frischen Risse des inneren Seitenbandes Verhandl d Deutsch Orthop Gesellsch *42* 235—237 1955

tenderness over the course of the medial collateral ligament especially in its upper half Slight laxity of the joint medially No drawer sign — X ray findings of the knee Pronounced general decalcification Slight ligamentous ossification at the femoral end of the medial collateral ligament some small bone shadows above the tibia spine *Diagnosis* Status post laesionem ligamenti collateralis medialis et ligamenti cruciati genus sinistri

These two cases show the consequences of an unplanned application of a cast for a knee injury Case 1 apparently sustained only a sprain, or possibly a stretching of the medial collateral ligament The now existing slight laxity may also be the result of muscular atrophy and widening of the capsule due to the joint effusion In spite of this she received a plaster cylinder for 10 weeks The plaster cylinder alone would not have led to these consequences, since, irrespective of the indication, proper application of the cast and proper after treatment will not cause such sequelae

The plaster cylinder was not applied in such a way that the immobilized knee became entirely free from pain When the knee is painless the patient must get up and walk and use his muscles to prevent atrophy The patient must be told to practice regular exercises with toes, ankle joint and the whole leg The distance he walks a day should be increased by 1 Km each week, i e, he should walk a daily distance of 8 Km in the eighth week, if this causes *no pain* In both cases these rules were not observed, though they are of paramount importance for the end-result

Again and again limitation of motion after plaster immobilization is reported Such cases as the two mentioned above are sent to us for after-treatment We ourselves have never seen such sequelae, although we treat many injuries of the knee joint Case 1, apparently only a sprain, did not become painless although a plaster cylinder was applied She could not walk and was bed-ridden There was nothing abnormal in the patient's general condition When she was sent to us eight months after the injury for after-treatment, she obtained a range of active motion from 180° to 110° after four weeks' exercises on the knee support (Vol II/fig 1574), and could walk without discomfort Case 2, apparently the more severe injury as can be juged from the pronounced bone atrophy and the slight ligamentous ossification, the patient also did not become free from pain and could not walk following application of the plaster cylinder The same mistake was made also in this case, although the general physical condition was normal After removal of the plaster cast and four weeks exercises in the Accident Hospital a range of motion at the knee was regained from full extension to 130° flexion, and after six weeks to a right angle With the help of a cane she can now walk without perceptible trouble This indicates that unsuitable treatment with insufficient immobilization for eight and five months respectively, was the cause of these ill-effects, namely the severely limited motion and the inability to walk

Questions We Should Ask Ourselves in Order to Avoid Failures When Treating Sprains and Ruptures of the Knee Joint

1 Have I carefully examined the knee joint to determine the degree of injury?

2 Have I, if the physical examination revealed lateral laxity of the joint, taken X-rays under abduction or adduction strain in order to determine

Damage to the Knee Joint Caused by Unsuitable Immobilization in a Plaster Cast

Immobilization of the injured knee joint in a plaster cast is regarded as harmful by many surgeons as they fear the joint may become stiff and the muscles weak This, in fact, occurs if the immobilization is not as complete as to exclude all pain and if the patient fails to carry out proper exercises *A plaster cast should only be applied if the collateral ligament is actually ruptured, as demonstrated by roentgen examination of the knee joint under strain, and if not more than one week has elapsed since the accident*

That a knee joint may be severely damaged by unsuitable plaster casts and insufficient exercises, is proved by two case histories taken from a paper by my former assistant Kromer [1]

Case 1 Anna P 40 years old a farmer s wife fell from a hay wagon on her left knee on June 26 1935 She was at once brought to a hospital where after an X ray a plaster cylinder was applied from the ankle to the groin As she stated she could not walk with this cast and *lay in bed most of the time* At the beginning of September i e after about ten weeks the plaster was removed but she could not even then bear weight Until December she remained permanently in bed not until the end of December did she begin walking short distances On Feb 28 1936 she was sent to the Accident Hospital for examination as pain still persisted

On admission Feb 28 1936 Tall strong well nourished woman General examination revals no abnormal findings Her left leg shows distinct muscle atrophy of thigh and calf The knee region is swollen its circumference measuring 2 cm more than that of the sound side There is a minimal effusion into the joint Toes and ankles of both feet show full range of active motion Range of active motion of left knee extends from 170° to 150° Further flexion is not possible passively because of spasm due to severe pain Passive motion of hip is free but active motion is not because of pain in the knee Pain is produced at the femoral attachment of the medial collateral ligament by abduction of the lower leg by passive hyperextension and by local pressure Lateral stability of the knee is not significantly impaired A drawer sign cannot be elicited With the help of two canes she walks very slowly and limps badly She cannot walk on tip toe *X ray findings* of the knee moderate decalcification of bones no signs of old or fresh injuries to the bones no Stieda Pellegrini s shadow no ligamentous ossification *Diagnosis* Status post distorsionem et laesionem ligamenti collateralis medialis genus sinistri

Case 2 Agnes H 35 year old farmer s daughter on Oct 2 1935 stumbled over an ant hill and fell She developed pain in her left knee on standing and walking The knee was swollen She applied compresses with aluminum acetate and massaged her knee As it did not improve she went to the doctor (on Nov 7) who treated her with different ointments and finally on Jan 9 1936 sent her to a hospital An X ray was taken and a plaster cylinder was applied from the mid calf to the mid thigh for five weeks Another X ray was taken after removal of the plaster On Feb 14 1936 a new cast was applied from the toes to the groin With this cast she was sent to the Accident Hospital on Feb 28 1936 i e almost five months after the injury It should be noted that *allegedly two persons were required to accompany her* Their fare was paid by the health insurance From the injury until admission to the Accident Hospital she was bedridden most of the time Not even after application of the plaster was she told to get up and walk — *On admission* Feb 29 1936 Patient of medium height and moderate strength General examination reveals no abnormalities After removal of the plaster cast the left leg is seen distinctly atrophic The normal contour of the knee is obscured Active motion of toes free of ankle joint limited by half Knee moves from 175° to 150° with pain on movements Severe contraction of antagonists at the attempt of further passive flexion or extension Passive movements of the hip are free Local

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1 Kromer 1937 Schadigung des Knieglenkes durch unzweckmaßige Ruhigstellung im Gipsverband Der Chirurg 9 377—380

21. Have I, in operative treatment, preserved and not excised a meniscus loosened at its attachment?

22. Have I taken X rays under abduction or adduction strain at the end of treatment?

82. RUPTURES OF THE CRUCIATE LIGAMENTS

Ruptures of the cruciate ligaments often accompany severe ruptures of the collateral ligament and always accompany dislocations of the knee. Isolated ruptures of the cruciate ligament are less frequent.

Origin. *Isolated ruptures of the anterior cruciate ligament* result from hyperextension, when a direct force strikes the anterior aspect of the knee joint. At the same time the ligaments and the capsule of the posterior aspect of the joint are torn.

Isolated ruptures of the posterior cruciate ligament result when a force strikes the proximal end of the tibia while the knee is flexed to a right angle, as occurs when the lower leg is fixed, and the femur is driven forwards, e. g., by the momentum of the body when the tibia hits against an obstacle. This may happen to motorcyclists when they hit a curb. Rupture of the posterior cruciate ligament is much rarer than that of the anterior one.

Site of the Injury. The cruciate ligaments are often avulsed with their bony attachment from the tibia (figs. 2271—2278, 2315—2320). Rupture of the ligament near its tibial end without bony avulsion occurs less often, while rupture in the course of the ligament (figs. 2284 k—m) or at its femoral attachment is uncommon.

Diagnosis. If the tibial attachment of the anterior cruciate ligaments has been avulsed and the bony fragment has been displaced towards the center of the joint, a 10° to 30° limitation of extension will result (figs. 2315—2320). In rupture of the ligament without bony avulsion, the joint can be overextended. In severance of the anterior cruciate ligament, the lower leg can with the knee flexed to 120° be displaced forwards on the femur (figs. 2284 h and l). In severance of the posterior cruciate ligament it can be displaced backwards (figs. 2269, 2284 i and m). In rupture of both cruciate ligaments instability in the anteroposterior plane is especially marked. The lower leg can then be displaced forwards and backwards (figs. 2284 h—m). In a simultaneous rupture of the posterior cruciate and the medial collateral ligament the leg can be rotated inwards to an abnormal degree (fig. 2265). These displacements can as a rule be observed in the first few hours only, i. e. before the joint becomes distended with blood and the capsule thickened due to the trauma. They can again be demonstrated after aspiration of the blood and local anesthesia of the joint space, thus excluding the reflex muscle contraction. The drawer sign, i. e. the instability of the joint in the anteroposterior plane, is most marked in old cases, treated by unsuitable methods, i. e., without immobilization and with early movement. As mentioned on p. 1508, both knee joints should be examined, since the uninjured knee may be loose as well.

the amount of gaping of the joint space in ruptures of the a collateral ligament and thus to determine the necessary period of immobilization?

3 Have I placed a 4 5 × 13 × 18 cm linden wood wedge under the knee to make it possible to take the follow-up X-rays under identical conditions?

4 Have I, on the first day after the injury, taken X-rays under local anesthesia if there is reflex contraction of the antagonists

5 Have I omitted local anesthesia when taking X-rays under strain, on the second or third day after the injury, in order to avoid loosening of early adhesions?

6 Have I omitted X-rays under strain after the third day?

7 Have I taken comparison X-ray of the sound knee with the linden wood wedge?

8 Have I avoided forceful extension of the knee in sprains and stretching of the ligaments (first and second degree injuries)?

9 Have I avoided applying a plaster cylinder in first and second degree injuries?

10 *Have I, within the first ten days after the injury, applied a plaster cylinder at a flexion angle of 170° in rupture of the collateral ligament* (third and fourth degree injuries)?

11 Have I omitted applying a plaster cast from the tenth day on, since the torn ligament cannot unite in the proper length after this time?

12 *Have I applied a plaster cylinder for 6 to 16 weeks only in those cases where X-rays of both knees under strain demonstrated the presence and the extent of rupture of the collateral ligament?*

13 Have I applied the plaster cylinder at 170° flexion and not in full extension or hyperextension?

14 Have I taken exact anteroposterior and exact lateral X-rays after application of the plaster cast to demonstrate that the joint space is well closed at the medial or lateral side and that there is a flexion angle of 170°?

15 Have I urged the patient to walk during the period of immobilization actively to elevate the leg as high as possible, and to exercise all other muscles of the body, if this causes no pain?

16 Have I maintained immobilization long enough and thus avoided loosening of the joint?

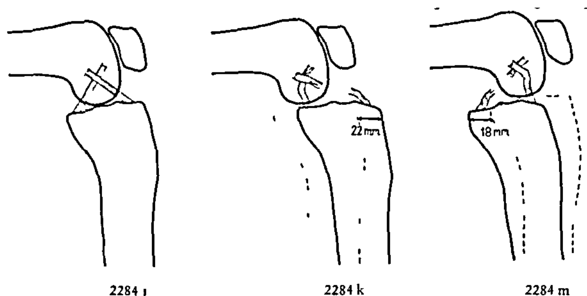
17 Have I measured and recorded the range of motion of the knee joint after removal of the plaster and then every week to follow the progress of motion?

18 Have I avoided massage and passive exercise as they irritate the knee joint, and lead to flexion contracture and ossification in first and second degree injuries and to loosening of the joint in third and fourth degree injuries?

19 Have I omitted exercises which cause pain?

20 Have I treated a rupture of the lateral collateral ligament when the joint space could be spread to more than 15 mm operatively and not conservatively?

elicited That the joint in fact becomes stable in all directions by sufficiently long immobilization is proved by the end results of dislocation of the knee where the cruciate ligaments are always torn (see pp 1560—1562) The man with dislocation of the knee, ruptures of both cruciate ligaments and the medial collateral ligament, pictured in figures 2284 h—m, after immobilization of 16 weeks regained joint stability in all directions and a good range of motion Thus it is not necessary to treat a torn cruciate ligament in a fresh dislocation of the knee by plastic operation



2284 j 2284 k 2284 m

Sketches re figs 2284 g—i showing the cruciate ligaments

Fig 2284 j—The cruciate ligaments are intact It is not possible to displace the lower leg forwards or backwards

Fig 2284 k—In rupture of the anterior cruciate ligament the lower leg can be displaced forwards

Fig 2284 m—In rupture or avulsion of the posterior cruciate ligament the lower leg can be displaced backwards Figs 2284 g—m are taken from a paper of Jorg Bohler s[1]

Treatment of Old Ruptures of the Cruciate Ligament

If old ruptures of the cruciate ligament cause severe trouble, which is exceptional, the ligament should be replaced by a plastic procedure Of many methods suggested, Hey Groves s method has proved best The joint is exposed through an anterior incision One hole is bored through the lateral femoral condyle to the femoral insertion of the anterior cruciate ligament, and another from the front of the tibia towards the tibial insertion A tongue-like strip of fascia lata, about 20 by 4 cm, is cut with its base distally It is passed through the femoral hole, the joint, and the tibial hole and sutured to the patellar ligament If the medial collateral ligament is also torn, a longer strip of fascia is chosen which is turned upwards from the tibia to the femur along the course of the medial collateral ligament and fixed there The medial collateral ligament can also be restored

[1] Jorg Bohler 1943 Rontgenologische Darstellung von Kreuzbandverletzungen Der Chirurg *16* 136—138

Complications after Ruptures of the Cruciate Ligaments Without adequate treatment the joint remains loose and sometimes gives way backwards or forwards Arthrotic changes may follow but they are seldom severe There are many patients with isolated ruptures of the cruciate ligaments who have no complaints and engage in all sports

Avoidance of Complications after Ruptures of the Cruciate Ligaments Complications can be avoided if the joint is immobilized over a sufficiently long period, i e as a rule twelve weeks, and if the muscles of the leg and all other muscles are exercised



2284 g 2284 h 2284 i

May 12 1943

FIG 2284 g—Lateral X ray of a reduced dislocation of the left knee joint similar to that in figs 2241 2242 No changes can be seen though the medial collateral and both cruciate ligaments are torn

FIG 2284 h—Comparison picture of fig 2284 g in anterior displacement of the lower leg as in fig 2270 (so called anterior drawer)

FIG 2284 i—Comparison picture of fig 2284 g in posterior displacement of the lower leg as in fig 2269 (so-called posterior drawer)

Treatment of Fresh Ruptures of a Cruciate Ligament

Treatment is carried out in the same way as in ruptures of the collateral ligament of third and fourth degrees (see p 1573—1575) If the bony attachment of the anterior cruciate ligament has been avulsed it can easily be reduced under local anesthesia by slight hyperextension (figs *2315—2318*) In this case the plaster cylinder is applied for eight weeks in full extension at 180°, but *not in hyperextension* In rupture of the cruciate ligament without bony avulsion the plaster cylinder is applied at a flexion angle of 170° for twelve weeks The reposition of the fragment and the position of the joint must be tested by X-rays (see p 1574)

End-results Bony union can be expected in the case of avulsion of the bony attachment Ruptured cruciate ligaments without bony avulsion will probably not unite However the joint becomes stable since the associated tears of the capsule and its ligaments especially of the dorsal side, unite so firmly that the drawer sign (the anteroposterior instability) can no longer be

skiing because in a fall the medial aspect of the joint is seldom subjected to a compressing force, but rather is opened up Usually a sprain or rupture of the collateral ligaments is mistaken for an injury of the meniscus

I have seen a few cases in which the posterior horn was torn during the so-called Russian Dance In this dance done from a squatting position the knee is alternately extremely flexed, while the other leg is flung forward with the knee fully extended In these cases the dancer felt a sudden violent pain in the knee, which for some time afterwards made walking impossible After the torn piece of the meniscus had been removed by operation, the histological examination showed that it was healthy and had not degenerated Like a transverse split through the center, tear of the posterior horn is caused by contusion

In the typical injury (sudden rotation of the femur on the fixed lower leg with knee joint flexed) the meniscus glides backwards as in every flexion of the knee Owing to the sudden rotation of the femur the concave edge of the meniscus may become wedged between the tibial and femoral condyles During the subsequent rapid extension of the joint the meniscus glides forwards and its unimpinged convex portion is suddenly pulled away from the impinged concave one The resulting tension may lead to a longitudinal tear of varying size running through the anterior, middle, or posterior portion of the meniscus (figs 2285—2288)

Location and Shape of Meniscus Tears Longitudinal tears are much more frequent than transverse tears or pedunculated tags At the first injury usually a small longitudinal tear occurs in the anterior horn (fig 2285), in the middle (fig 2286) or in the posterior horn (fig 2287) Fresh injuries cause enlargement of the tear by repeated locking of the separated portion However, a longitudinal tear from the anterior to the posterior horn (fig 2289) can occur at the first accident In rare cases the separated portion slips into the middle of the joint and comes to lie near the cruciate ligaments (fig 2290) in the first injury This kind of lesion is called a bipartite meniscus or bucket handle tear In degeneration of the meniscus two or more longitudinal tears may occur (tripartite meniscus, fig 2288) The plane of cleavage usually runs obliquely from the convexity downwards towards the middle of the joint Thus the base of the meniscus remains preserved (figs 2299, 2300) The separated portion is usually 4 to 8 mm wide We have also seen some only 2 mm wide Complete detachment of the whole meniscus occurs only in ruptures of the collateral ligament and in fractures of the tibial head In such cases the rupture does not involve the fibrocartilaginous substance but the capsular attachment

Transverse tears (fig 2292) due to contusion do not traverse the whole width of the meniscus but somewhat less than half of it Repeated injuries may lead to anterior or posterior longitudinal tears starting at the end of the transverse tear (fig 2294) If they increase in size, pedunculated tags of a varying length will result which later on become knob-like (figs 2295, 2296) These tags sometimes project into the joint or are folded outward In the latter case they can be palpated easily from outside though this is rare

as described on p 1577 Lange has accurately described the reconstruction of the cruciate ligament in his text-book of operations

We avoid wire suture of the cruciate ligament since these may cause metallic disturbances of the knee joint

83 INJURIES OF THE MENISCI

Definition In the last few decades such an enormous literature has accumulated about the causes, recognition, treatment, and disability evaluation concerning injuries to the menisci, that it is impossible to keep abreast of it Some of the papers contain statements that seem obscure and incorrect Clarity will be achieved only when the concept of injury of the meniscus has been accurately established and sharply defined We should speak of an injury of the meniscus (tear through the body) only if the fibrocartilaginous tissue is affected as in figures 2285—2296, 2299, 2300, 2307, 2308, but we should not include so called combined injuries, in which the attachments of the meniscus and the loose connective tissue outside of the fibrocartilage (capsule tear) are torn and stretched, combined with rupture of the collateral ligament or rupture of the collateral and cruciate ligaments with avulsion of the posterior portion of the joint capsule or bone fractures as in figures 2284 a—f 2301—2304, 2345

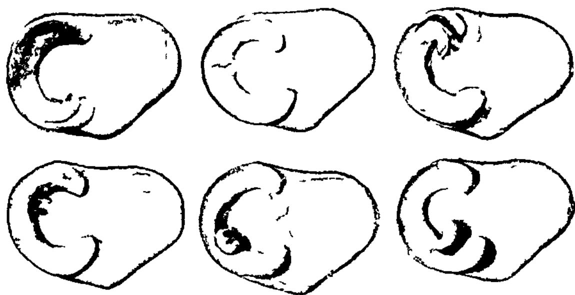
These criteria are of great importance for the treatment and prognosis inasmuch as the split fibrocartilaginous meniscus generally cannot heal whereas the surrounding vascular connective tissue will unite with a firm scar without any subsequent disturbance, provided the main injury, i e, ruptured collateral ligament and torn capsule is given suitable treatment by immobilization of suitable duration

Many laymen and also sports physicians regard most injuries of the knee even slight sprains and contusions, as injuries of the menisci This explains why one can frequently hear that a meniscus has been cured by massage and irradiation

Traumatic Origin of Injuries of the Menisci Tears in the fibrocartilaginous tissue of the meniscus (tears through the body) will occur when the femur suddenly and unexpectedly rotates on the fixed lower leg while the knee is more or less flexed and is bearing the entire body weight Inward rotation of the femur injures the medial meniscus, and outward rotation the lateral meniscus If the force is slight only contusion will result otherwise there will be a minor or a major tear Such injuries may have different causes, e g slipping or stumbling, trying to recover oneself from falling or jumping from a height It may further occur when the kick-starter of a motorcycle suddenly recoils, or when the chain of a bicycle breaks or jumps off the sprocket while riding uphill so that the pedals slip In addition to these possibilities, a meniscus is frequently torn in certain sports such as tennis and especially in football When a person falls to his knees as a consequence of such an indirect injury, it is not this second direct trauma to the joint that causes the injury of the meniscus, but the rotation that preceded it Although a great deal has been said and written about it a meniscus seldom gets torn in

spots, demonstrating that development took place over a period of time by repeated injuries As we operate only when the signs of a torn meniscus are clear-cut, we have found bucket handle tears in 55% of our operated cases

Relationship Between Meniscus Injuries and Degeneration Many authors have considered the meniscus tear as closely related to degeneration of the *meniscus* Tobler has expressed the opinion that only a previously diseased meniscus can tear He and many others have found that degeneration of the meniscus begins as early as at the age of 25 and sometimes even earlier



2291—2296

Fig 2291 top row left—Fresh pedunculated tag at the anterior horn The split is extended obliquely towards the middle of the concave margin

Fig 2292 top row center—Transverse tear in the middle For excision the posterior flap is detached in a length of 5 to 6 mm The anterior flap is excised with a narrow strip extending toward the anterior horn so that it can easily be drawn out

Fig 2293 top row right—Pedunculated tag at the posterior horn The split is extended anteriorly to the anterior horn so that a 3 to 4 mm wide strip is removed

Fig 2294 bottom row left—Transverse tear with longitudinal tears anteriorly and posteriorly The flaps are excised in the same way as in fig 2292

Fig 2295 bottom row center—Old thickened pedunculated tag attached in front For excision the tear is extended towards the anterior horn

Fig 2296 bottom row right—Old thickened pedunculated tag attached behind Excision is carried out as in a fresh pedunculated tag (fig 2291) Pedunculated tags often cause locking of the joint and effusions

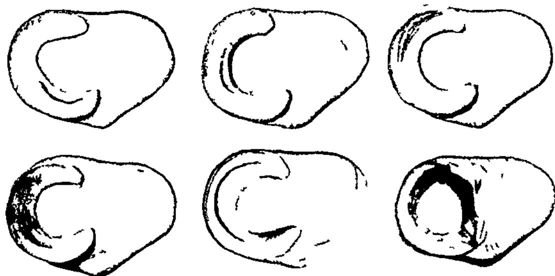
Degeneration is said to be frequent at the age of 40 and almost general at the age of 50 Slany,[1] at my request, opened 400 knee joints in 200 autopsies and examined the 800 menisci macroscopically and more than half of them also microscopically Macroscopic examination revealed no changes up to the 30th year of life Changes were detected in 16% of the menisci up to the 40th year, in 23% up to the 50th year, in 39% up to the 60th year, in 53% over 60 years of age Meniscus tears, however occur most frequently between 25 and

[1] Slany Autoptische Reihenuntersuchungen an Kniegelenken mit besonderer Berucksichtigung der Meniscuspathologie Arch orth u Unfall Chir *41* 246—286, 1942

Pedunculated tags also develop from transverse tears of the posterior horn (fig 2296)

We have never observed *abnormal mobility or abnormal loosening* of an uninjured meniscus We have the impression that such diagnosis is as a rule an excuse when no pathological lesion can be found, at operation

Gradual Tearing of a Meniscus The first trauma only rarely will cause a tear through the entire length of the meniscus As a rule a short split results



2285–2290

Figs 2285–2287 —*Top row left to right* Longitudinal tears of the anterior middle and posterior portions of the meniscus In operating on a longitudinal tear of the anterior portion of the meniscus the split should be extended anteriorly and posteriorly into the concave margin of the meniscus and only the separated portion of the meniscus should be removed In longitudinal tears of the middle and posterior portions the split should be extended to the anterior horn since the meniscus could otherwise not be drawn forwards The separated portion of the posterior horn is then cut off and removed

Fig 2288 —Bottom row left Multiple longitudinal tears in a degenerated meniscus The split which is nearest to the base is extended anteriorly and posteriorly into the concave margin and the whole separated portion removed

Fig 2289 —Bottom row center Longitudinal split through the whole meniscus without displacement

Fig 2290 —Bottom row right The separated portion of the meniscus is displaced towards the middle of the joint and lies next to the cruciate ligaments (bucket handle tear) This is the commonest form of meniscus injury We have found it in 55% of our operated cases The separated portion still remains fixed in front and behind and is folded upon itself This obstructs full extension and flexion

which increases in size with repeated, sometimes trivial episodes after weeks months or years Locking of the meniscus occurs suddenly sometimes even when a person turns over in bed Finally the separated portion is displaced into the middle of the joint *and comes to lie next to the cruciate ligaments (bucket* handle tear, fig 2290) Permanent locking of the joint results If the operation is performed within the first few days one can sometimes see that one part of the tear has already been scarred whereas another part shows fine hemorrhagic

3 Examination of the patient either lying or sitting with both legs bare
4 Pulsation of arteries on the dorsum of the foot and behind the medial malleolus, on both legs
5 Patellar tendon reflexes
6 Reactions of the pupils to light and convergence

(a) *Inspection*

7 If possible, the patient should walk about the room
8 Both legs are inspected and compared with each other from in front, from behind, and from both sides
9 Ascertain whether changes of shape or color of the legs can be seen (flat feet, knock-knees, circulatory disturbances such as varicose veins, cyanosis, swelling, muscle atrophy, signs of injuries such as excoriations and bruises
10 The patient should try deep knee bending
11 He should stand on each leg alternately
12 Examination of the stability of both knees during standing while the patient shifts his weight from one leg to the other
13 Examination of both legs in the lying or sitting position The patient should sit on the edge of the chair with the knees extended and both heels resting on the floor
14 *Ascertain whether both knee joints can be fully extended*
15 Examine active motion of all joints of both legs from the toes to the hip, first on the sound, then on the injured side, then both sides at once
16 If the motion of a joint is limited can it be further moved passively?
17 In limited motion of a joint its range of motion should be accurately measured with Moltgen's goniometer The range of motion should be written down and compared with that of the uninjured side

(b) *Palpation* Not until all the above examinations have been made may the patient be touched

18 Palpation of the knee to find an effusion or thickening of the capsule
19 Palpation for firmness of the muscles on powerful contraction especially the vasti
20 In muscle atrophy the circumferences should be measured 10 cm above the upper edge of the patella and 10 cm below the joint space on each leg
21 *Pressure on the anterior part of the tibial head of both legs — is this painful?*
22 Examination of the collateral ligaments for lateral stability in full extension and at a flexion angle of 160° (figs 2167—2170) with the muscles completely relaxed
23 *Examination of the collateral ligaments and the menisci for pain on adduction or abduction* (figs 2167—2170)
24 Examination of the knee joint in passive flexion and extension and simultaneous adduction or abduction for intermittent pain and snapping in the joint
25 Examination of the cruciate ligaments for firmness with the knee flexed at an angle of 110° to 120° by displacing the tibial head forwards and backwards on the femur (figs 2269, 2270, 2284 g—m)

35 years after which they decrease rapidly After the 55th year they are seen only exceptionally If the genuine meniscus tear is the normal result of degeneration, it should occur more often with advancing age, and not less often However the sudden uncoordinated twisting movements with the weight on the flexed knee that are essential to the origin of a traumatic tear of the meniscus are no longer carried out with advancing age At our operations we have only rarely seen yellow discolored degenerated menisci with multiple tears

Origin of Meniscus Injuries Occupational Overstrain This type of injury is mainly observed in miners, layers of tiled and parquet floors, gardeners stone breakers, who overstress their menisci by prolonged kneeling or working with their knees in extreme flexion This leads to fatigue of the tissue, exceeding its elasticity, and to multiple tears, which remain undetected, the tissue already having become partially necrotic These existing tears only become apparent when a sudden rotational strain causes impingement of the meniscus and locking of the knee joint, without any appreciable violence These menisci show yellowish discoloration We have only rarely seen such cases of degenerated menisci

Examination in a Suspected Fresh Meniscus Injury After the personal data (age, occupation, adress, etc) and body height and weight have been recorded, the examination is performed in a way similar to that described on pages 1507—1512 as follows

I The history is especially important in injuries of the meniscus, as the diagnosis can often be made from it with considerable accuracy The following questions are asked

1 When did the accident occur?
2 Where did the accident occur?
3 How did the accident occur (slipping torsion, fall)?
4 Was the pain slight or severe?
5 Was there a sensation of locking?
6 What kind of incapacity followed?
7 Was getting up and walking possible at once?
8 After what length of time was weight bearing and walking again possible?
9 Could the knee be extended?
10 Was an attempt made to extend the knee by firmly holding it or by rotating it?
11 Did someone pull on the leg in order to extend it?
12 Did swelling or an effusion occur at once or not until the following day?
13 Was the swelling slight or severe?
14 Could the patient continue to work?
15 What was the first treatment (compresses or immobilization by a splint or in plaster)?
16 Had the knee joint been injured before?

II Objective Findings

1 General condition
2 Previous diseases or other injuries

Features of a Fresh Injury to the Meniscus At the moment of injury a sudden severe pain is felt in the joint, which sometimes makes standing impossible The pain with small tears soon subsides but with big tears persists Displacement of the separated portion into the middle of the joint makes full extension impossible There is a permanent locking at an angle of between 140° and 170° The portion displaced from the arc to the chord, has become too long and folds on itself at the front and at the back (fig 2290) This fold can sometimes be palpated or even seen in front of the joint With long continued locking the anterior and posterior folds become flattened more and more, so that at last extension is limited by only 4° to 6° Usually in fresh cases the joint is *not swollen* and shows *no effusion* on the first day If an effusion develops, it appears on the second day, and is not severe This must be emphasized since the opposite is often maintained In injuries of the medial meniscus adduction of the lower leg will produce pain of varying degree at the medial side of the joint (pain on adduction medially, fig 2170) In injuries of the lateral meniscus pain is produced at the lateral side of the joint by abduction (pain on abduction laterally, fig 2168) In injuries of the anterior horn a severe pain is produced by attempting to overextend the knee Extreme flexion causes severe pain in an injury of the posterior horn In addition, in injuries of the medial meniscus, pain is usually produced in the joint space if the lower leg, with the knee at a right angle is quickly rotated externally, and in injuries of the lateral meniscus, if the lower leg is quickly rotated internally If the joint, with simultaneous adduction, is extended and flexed, a snapping is felt in some instances of a torn medial meniscus Pain on extension and flexion subsides or disappears if performed in abduction of the knee In rupture of the lateral meniscus, the opposite is true There is marked tenderness over the anterior or posterior joint-space whereas there is complete absence of tenderness over the edges of the femoral and tibial condyles and the collateral ligaments

Diagnosis of a Fresh Meniscus Injury Diagnosis of a fresh injury to the meniscus is certain in the presence of the following signs

1 Adequate trauma (sudden unexpected torsion strain without direct violence to the knee)
2 Immediate pain in the joint
3 Absence of an effusion
4 Pain at the medial joint space on adduction or at the lateral joint space on abduction
5 Pain on attempted overextension or extreme flexion
6 Pain on rotation of the lower leg, with the knee flexed to a right angle, the pain being felt on external rotation in the case of tear of the medial meniscus and on internal rotation in the case of tear of the lateral meniscus
7 Tenderness distinctly limited to the joint-space, whereas the upper margin of the tibial head and the edges of the femoral condyles are not tender on pressure (very important!)

If, in addition to the above signs extension is limited at an angle of 140° or 170°, the diagnosis of bipartite meniscus (bucket handle tear) is certain In

26 *Examination for pain on rotation The lower leg, with the knee flexed to a right angle, is grasped above the ankle and quickly rotated outwards and inwards*

27 Examination of mobility of the patella by pushing it medially laterally, downwards, and upwards with the muscles relaxed

28 Place the hand over the knee and examine for crepitation in flexing and extending the knee freely and while pressure is exerted upwards at the heel

29 Examination for tenderness over the whole joint space in extension

30 *Examination for tenderness of the whole joint space with the knee flexed to a right angle The thumb is placed anteriorly, the index and middle finger are placed posteriorly and the whole joint is palpated*

31 *Examination of the joint space for tenderness, with the knee at a right angle, in internal and external rotation The lower leg is rotated while the heel rests on the floor*

32 Examination for tenderness over the femoral and tibial condyles and the capsular attachments

33 Examination of the ligamentous attachments and the hamstring tendons for tenderness

(c) *X-ray-Examination* To complete the examination and to confirm the diagnosis X-rays of both knees should be taken exactly anteroposteriorly and laterally to exclude an injury to the bones or a disease (e g arthrotic changes) or a loose body The usual roentgenograms are negative in simple meniscus injuries but they are important for later disability assessments

Pneumoradiography Figures 2297—2303 show that meniscus and cruciate ligaments can be demonstrated by injection of contrast media into the joint These examples are taken from a paper by my former assistant Dr Kromer[1] *who described the technique and the significance of the findings A more detailed* presentation is contained in the latest edition of his book Complete tears of the meniscus with displacement of the separated portion can be readily demonstrated by this method while small tears can often be seen only with difficulty Meniscus tears which yield no certain signs on physical examination can be confirmed by this method

Jorg Bohler[3] has described the technique of the pneumoradiography as follows 60—100 cc air are used as contrast medium and are injected into the joint cavity with a syringe The suprapatellar pouch is then firmly wrapped with an elastic bandage to force as much air as possible into the joint space X-rays are taken with the patient lying on the side The part of the joint space under suspicion is at the same time spread under strain At first an antero-posterior and a lateral X-ray are taken then four tangential X-rays of the suspected meniscus to show its whole circumference With this technique most of the doubtful cases can be clarified

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1 Kromer Die rontgenologische Darstellung des Kniegelenkinnenraumes durch Kontrast fullung und die Deutung der Befunde Der Chirurg 12 9 449—463 1937

2 — Der verletzte *Meniscus 3 rd Ed Wien Maudrich* 1955

3 Jorg Bohler Di Pneumoradiographie des Kniegelenkes Die medizinische Welt 19 742—743 1950

the joint space, and slight pain on adduction, or abduction respectively These signs will soon disappear

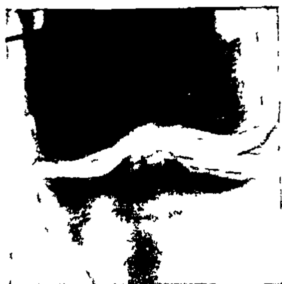
Diagnosis of old meniscus injuries may be difficult It is important to elicit the history of the type of trauma and of the recurrence of locking which



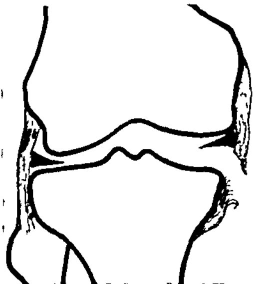
2301 Nov 13 1933



2302 Nov 18 1933



2303 Jan 27 1934



2304 July 4 1938

Fig 2301 —Rupture of the lateral collateral ligament and the capsule near the femoral attachment Air has accumulated between the synovial and fibrous part of the capsule This produces the false impression of a meniscus detached at its base The meniscus is not injured the superimposed accumulation of air is caused by the passage of the popliteal tendon After Kromer

Fig 2302 Pneumoradiogram of a rupture of the medial collateral ligament under abduction strain The medial joint space can be broadened to three times its normal width but only in slight flexion of the knee The cruciate ligaments are not torn which is confirmed by this X ray The width of the articular cartilage can clearly be seen as well as the medial meniscus which is torn off the tibial head and shows a slightly irregular distal contour Marked escape of air at the site of the tear in the capsule The air extends to the femur Healing after 12 weeks immobilization in plaster After Kromer

Fig 2303 —Rupture of the medial collateral ligament also in the region of the tibial attachment After Kromer (Der Chirurg 1937 Heft 12)

Fig 2304 —Coronal section re fig 2302

tears without displacement of the separated portion long-lasting limitation of extension is rare

Contusion of the Meniscus If the acting force is not severe, contusion and not a tear of the meniscus will result At first there is tenderness limited to



2297 May 16 1936



2298 April 9 1934



2299 *July 23 1934*



2300

Fig 2297 Pneumoradiogram of a normal knee joint under abduction strain The abduction has produced an air space also below the medial meniscus All contours and structures of the joint are well shown viz the medial meniscus the cartilage of the articular surfaces and the cruciate ligaments which can be differentiated into anterior and posterior The lateral joint space is compressed by the abduction So the wedge shape of the lateral meniscus cannot be seen though the upper and lower compartments of the capsule can be seen After Kromer

Fig 2298 Normal knee joint after injection of a contrast medium with double contrast effect Medially a clearly defined wedge of meniscus representing the optical cross section Laterally the wedge of the meniscus is *less clearly visible Below* the meniscus is an accumulation of air following the course of the popliteus tendon The full width of the articular cartilage can be well seen The cruciate ligaments are vaguely shown but details are obscured by multiple overlapping After Kromer

Fig 2299—Meniscus tear near the capsule with displacement of the separated portion into the middle of the joint X ray taken under abduction strain At the medial part of the joint space an accumulation of air replaces the meniscus shadow The portion of the meniscus near the base is tilted and gives the impression of an abnormal plane of cleavage of the tear The shadow of the displaced portion of the meniscus is visible near the tibial spine Operative findings complete *longitudinal tear with displacement of the torn portion into the middle of* the joint (bucket handle) as in fig 2290 After Kromer

Fig 2300—Coronal section re fig 2299 Rupture of the medial meniscus from above medially downwards laterally The margin is not tilted as the joint has no been filled with air The separated portion is displaced into the middle of the joint The base of the meniscus is preserved so the joint will become normal again after excision of the separated portion

on more than twenty cases of this kind These mistakes can be avoided by accurate examination determination of the blood sedimentation rate and by careful consideration as to whether operation is indicated

The *differential diagnosis* between a tear of the medial meniscus, a sprain or rupture of the medial collateral ligament and the painful knee in heavy women has been described on page 1511

Complications after Conservative Treatment of Injuries of the Meniscus Small tears of the meniscus probably heal within a short time Big tears are usually followed by complaints such as foreign body sensation, instability of the knee on walking, and pain especially when walking downhill The thigh muscle bulk as a rule decreases There is a frequent sensation of displacement, and the recurrent locking causes serous effusions Arthrotic changes may supervene after years The acute signs of a bucket handle tear may subside and full extension may be regained after some weeks in spite of the existing displacement, because the anterior fold is compressed Years may follow without any significant trouble

Complications after Operative Treatment and Energetic After-treatment of Injuries to the Menisci These may ensue at once or as late as after months or years We differentiate early and late complications

Early Complications	*Late Complications*
1 Division of geniculate branch of the saphenous nerve	1 Secondary tears
2 Severe joint effusions	2 Limited rotation
3 Severe muscle atrophy	3 Arthrotic changes
4 Considerable congestion of the lower leg	4 Formation of loose bodies
5 Acute bone atrophy	5 Muscle atrophy
6 Infection and empyema, ankylosis, amputation, or death	6 Limitation of motion and pain

Avoidance of Complications after Conservative and Operative Treatment of Injuries to the Meniscus The complications can be avoided if the separated portion is removed through a small incision, if the base of the meniscus is preserved on principle, and if all after-treatment with massage, passive motion and overheating is avoided

Conservative Treatment of Injuries to the Meniscus

Reduction of a Displaced Meniscus We attempt reduction if the displacement has occurred at work or on a walk or if an early operation cannot be performed This will usually succeed if the patient sitting on a table has his legs hanging down and if with appropriate rotary movements downward traction is exerted Sometimes there is an audible click indicating that reduction has been achieved In severe pain we sometimes use local anesthesia Reduction is possible only if a pedunculated tag or a bucket handle has been caught between the femoral and tibial condyles If the separated portion of a bucket handle has been displaced into the middle of the joint, so that it has come to

occurs in external rotation of the lower leg or when the fore foot gets caught in some object Serous effusions sometimes intervene with repeated locking, but they are rarely severe The patient usually has a foreign body sensation in the joint and experiences trouble in walking downhill The thigh muscles are weaker than on the sound side There is usually little pain on adduction or abduction, on overextension or flexion, on rotation or pressure over the joint space The limitation of extension in a bipartite meniscus disappears in time, in spite of the displacement persisting, since the fold in the anterior joint space is compressed after a few weeks In recurrent locking there is usually muscle atrophy of moderate degree After years arthrotic changes may supervene Pedunculated tags displaced into the joint sometimes cause erosion of the cartilage of the femoral condyle

In dubious cases it is best to wait until definite locking occurs The patient is requested to come at once as the signs will then be clear It may take several days or weeks before the signs are definite At each examination all signs must be accurately recorded, especially point tenderness and pain on rotation

With this form of examination our diagnosis was verified in 1012 out of our last 1078 operated cases, i e in 93 87% We are fully aware that some cases of meniscus injury have remained without operation as at the time we failed to recognize them as such This is of no consequence because the patients will report again with clear signs when new troubles set in

Warning against Painful Knees in Young Girls Young girls often report with knee-pain which has developed gradually but is sometimes attributed to an injury They complain of spontaneous pain Examination reveals indefinite tenderness over the joint space and pain on rotation Palpation is difficult due to the covering of fat around the knee Operation should be avoided unless definite signs can be found and tear of the meniscus has been confirmed by pneumoarthrography

Locking of the Joint by Tags of the Cruciate Ligaments, Sclerosed Villi of the Infrapatellar Fat Pad, and Tumors of the Capsule If an anterior cruciate ligament is ruptured at its femoral end the stump may become caught between the joint ends The same may apply to pedunculated villi of the infrapatellar fat pad and capsular tumors The signs will be similar to those of a pedunculated tag of the meniscus Operative treatment will remove the trouble

Loose joint bodies may cause locking and thus be mistaken for an injury of the meniscus If the loose body lies between the joint ends there may be pain on adduction or abduction and tenderness over the joint space Loose bodies can usually be seen in the X-ray *especially with a contrast medium In only* one case have we observed loose bodies with concomitant tear of the meniscus Loose joint bodies are often observed after complete excision of the meniscus (see case history on p 1606)

Arthrotic changes and painful knees in heavy women (see pp 1622—1626) cannot be misdiagnosed after accurate examination

In incipient tuberculous arthritis the knee joint has often been opened because injury of the meniscus was wrongly suspected Vulliet[1] has reported

[1] Vulliet Z Unfallmedizin *30* 18—62 1936

function within a few weeks, and there will usually be no late complications such as secondary tears or arthrotic changes

Contraindications to Operation The operation should only be performed in the presence of definite signs of injury to the meniscus Other cases should be postponed until the signs become clear We do not advocate exploratory arthrotomy in the presence of uncertain symptoms, since urgent operation is never vital as in some intra abdominal operations The condition of the skin of the knee and all over the body must be normal, there must be no suppuration such as pustules, furuncles, abscesses or a paronychia The existence of tonsillitis or any other inflammatory disease must be excluded Normal local and general conditions must be present The operation should not be carried out in the presence of a severe effusion since it obscures a definite recognition If the range of motion is limited to less than 90°, operation should be delayed until the cause of this disturbance has been abolished

Preparation of the Skin Formerly we applied compresses soaked with alcohol the night before the operation Since they sometimes caused pustules we have not used them for several years and operate without any preparation of the skin It is shaved just before operation and not the night before We have observed practically no skin disturbances

The following are required for a meniscectomy

1 General, local or spinal anesthesia
2 Two rubber bandages, one for exsanguinating the leg, the other as a tourniquet
3 Small hooks
4 A strong meniscus forceps to grasp the meniscus
5 A tenotome
6 Scalpels, forceps, scissors, dissecting forceps, wound retractors, etc , as in all operations

Positioning the Patient The patient's knee is flexed to a right angle and his lower leg hangs over the end of the table

Anesthesia Formerly we used spinal and sometimes local anesthesia The latter has the disadvantage that the operation cannot be performed in a bloodless field Since 1926 we have operated upon most patients under general anesthesia, as the operation is short and the patients are as a rule healthy Any other form of anesthesia can be used as well

Operation X-rays of both knees are displayed so that the surgeon can once again rule out injuries of the bones and diseases of the bones or the joint As soon as the patient is anesthetized one rubber bandage is firmly wound round the leg from the toes upwards to the thigh to exsanguinate the leg, and the other rubber bandage is then applied as a tourniquet The end of the table is dropped so that both lower legs hang down After draping the patient a 5—6 cm long skin incision is placed from the femoral attachment of the medial collateral ligament towards the patellar ligament The incision ends at the level of the joint space It should not extend too far anteriorly, so that the patient will not kneel on the scar later on As the incision runs parallel with a branch of the saphenous nerve, damage to the latter can easily be

lie beside the cruciate ligaments, reduction is no longer possible These cases, however, cause less pain Some patients reduce their meniscus by shaking the joint or have their fellow workers pull on their leg According to Kromer some reduce their meniscus by slightly abducting the injured leg and shifting their body weight to the medial margin of the foot Thus, they increase the valgus position of the knee and widen the medial joint space Then they fully extend their knee by means of their hands and the separated portion slips back often with considerable pain

Treatment of Injuries to the Meniscus by Plaster Casts Small superficial tears probably heal by themselves through scar formation, but in extensive tears this is not possible Thus it is of no avail to apply a plaster cast for several weeks or 2—3 months We have met patients who had received four to six plaster casts for alleged tears of the meniscus within a few years In the patients whose meniscus injuries are said to have been healed by plaster casts, the diagnosis would first have to be proved Every loosening of the meniscus outside the fibrocartilaginous body, as it occurs in rupture of the collateral ligament (figs 2284 a—f, 2301—2304), must be excluded as it heals with a firm scar and without later disturbances, if the joint is immobilized for a long enough period As 90% of all injuries to the meniscus can be confirmed by pneumoradiography, advocates of the treatment by plaster casts should give roentgenological evidence of the correct diagnosis To our knowledge this evidence has not yet been adduced They should also demonstrate that no now complaints or locking have appeared for at least two years

Treatment of Injuries to the Meniscus by Massage and Irradiation These measures are often used as well as passive motion hot air, diathermy, ultrasonic therapy, and irradiation with lights of different colors If permanent healing results from these methods it only proves that the patient had been suffering from a sprain and not a tear of the meniscus In genuine tears of the meniscus these measures cannot succeed Often they irritate the joint and delay the necessary operation

Treatment of the Injuries to the Meniscus by Unna s Paste Dressing If for some reason operation is not possible or if the diagnosis is not yet definite, an Unna s paste dressing is applied from the web of the toes to the knee and an elastic bandage is wound around the knee The complaints as a rule subside quickly and walking downhill becomes easier at once

Operative Treatment of Injuries to the Meniscus

Time of Operation When the diagnosis of a torn meniscus has been established so far as possible from the signs given on p 1591, the torn portion should be excised as soon as possible i e within the next few days or weeks in order to prevent new impingement and effusions

Method of Operation The operation should be performed carefully and must not damage the extensor mechanism or the collateral ligaments However the incision should be big enough to afford a good survey of the joint Only the torn portion of the meniscus should be excised, whereas the uninjured base of the meniscus should be preserved If the operation is performed carefully and in accordance with these rules the joint will in most cases regain full

If the tear in the posterior horn cannot be displayed in this way, a longitudinal incision is made behind the collateral ligament and a transverse incision through the capsule Thus pedunculated tags of the posterior horn can be removed

The important base of the meniscus wedge remains untouched

If no tear is found at operation it is our principle not to remove the meniscus

After removal of the torn part of the meniscus the synovial membrane, the fat pad and the articular cartilage of the femur and the tibia are examined and, if necessary, smoothed Frayed out fibers of the remaining meniscus are also removed Now the lower end of the table is again elevated to extend the knee, and the edges of the capsule and the skin come together without tension

Two or three fine sutures are placed through the synovial layer of the capsule in such a way that they do not project into the joint According to Boominghaus no further sutures are applied to close the synovial capsule These can be omitted because we have observed that no effusion in the joint followed treatment of traumatic lacerations of the joint cavity, in which we never bury any stitches in the deep layers The fibrous capsule is closed with 5 or 6 fine stitches On principle the clamped vessels are not ligated, for the reasons given in Vol I/p 153 In spite of this we have never encountered a subcutaneous blood effusion The skin edges are accurately apposed with towel clips and sutured Thus, only 6 to 8 stitches are buried With the use of this technique only 8 to 10 minutes are usually needed from the incision to the suture of the skin

If an anterior drawer sign is present due to a concomitant rupture of the anterior cruciate ligament, the edges of the fibrous capsule are overlapped for 0 5—1 cm and sutured in this position This double-breasting of the fascia gives the joint greater stability

Pressure Bandage After suture of the skin the wound is covered with a small sterile dressing soaked with a few drops of balsam of Peru It is fixed with mastisol or adhesive plaster No circular bandage is applied as it might bind Then, with the knee at 140°, a 10 cm wide cellulose roll is applied around the knee It extends beyond the joint space distally by 2—3 cm, and proximally by a hand s breadth to include the suprapatellar pouch It is fixed by a gauze bandage applied under firm pressure

The tourniquet is removed after application of the pressure bandage

In injuries of the lateral meniscus an adequate incision is made laterally Here the operation is generally more difficult

Since we have stopped suturing the synovial capsule, *effusions in the joint* are rare, whereas formerly they occurred in every fourth case

Foreign body cysts, as have been reported after ligatures of vessels, have never been observed by us as we ligate no vessels on principle

Infection of the joint has never developed In only three of 1000 cases stitch fistulae developed 2—4 weeks after operation which closed again in 3—4 months, after a few threads had come out The function of the knee became normal in spite of this complication

avoided (figs 2305, 2306) Both skin edges are walled off with sterile towels The upper anterior margin of the tibial head is palpated, 2—2 5 cm above it a 4—5 cm long transverse incision is placed through the fibrous and synovial capsule The fat pad should not be injured, as there will be much bleeding if it is incised If the capsule is severed more distally the base of the meniscus can easily be injured As a rule some clear, yellowish fluid, only rarely blood-stained, escapes the joint In old cases it will be brownish The fluid is squeezed out by the assistant who presses his hands on the popliteal region and the suprapatellar pouch When the fluid has been sponged out, the small hooks are inserted and the anterior half of the meniscus can be viewed In fresh injuries of the meniscus sometimes tiny spots of fresh hemorrhage are seen in the tear With the lower leg dependent there is a good view of the joint as it is drawn somewhat apart in this position However, if the knee is flexed with the foot resting on the table the tibia will be pressed against the femur In addition, it is much easier to rotate the dependent lower leg inwards and outwards and to adduct and abduct it for appropriate exposure of the meniscus The anterior cruciate ligament can always be inspected well

In a bucket handle tear the torn part displaced into the middle of the joint is seen at once The front portion of the torn part is divided with the scalpel at the anterior horn The strong catch forceps are applied to the torn portion, which is pulled forwards and divided with the tenotome at the posterior horn

Also tears of the anterior horn and the mid portion (figs 2285, 2286, 2288, 2291 2292, 2294—2296) can be well seen The line of the tear is extended forwards and backwards, obliquely towards the concave margin of the meniscus to excise the torn portion

If no tear can be seen in spite of definite symptoms the tibial side of the meniscus is palpated with a small blunt hook In a few cases a tear that has not yet reached the femoral side can be detected

Tears of the posterior horn come into view only when the synovial capsule is divided inside the medial collateral ligament as far as the middle of the ligament, or if necessary even further back, but without incising the ligament itself If the meniscus is then strongly pulled forwards with a sharp retractor, tears of the posterior horn can be also seen It also helps if the lower leg is pushed forwards by pressure exerted on the popliteal region Thus the torn portion sometimes slips into the joint In these tears an oblique incision is made from the anterior end of the tear towards the anterior horn and a 3—4 mm wide strip of the concave margin is included This strip is detached at the anterior horn and grasped with the meniscus forceps By strong traction a pedunculated tag of the posterior horn as in figure 2293 can be pulled out anteriorly In longitudinal tears of the posterior horn as in figure 2287 the torn portion slips into the middle of the joint like a bucket handle and can be divided at the posterior horn with a tenotome In this way we have generally succeeded in removing torn portions of the posterior horn as well If one does not divide a long enough strip at the anterior end of the tear it will be difficult to pull the torn part of the posterior horn forwards

bit less firmly, or the cut edges of the bandage are held together by two or three strips of adhesive plaster

Further Treatment The patient remains on the Braun splint for nine days After 8—9 days the stitches are removed On the tenth day an Unna's paste

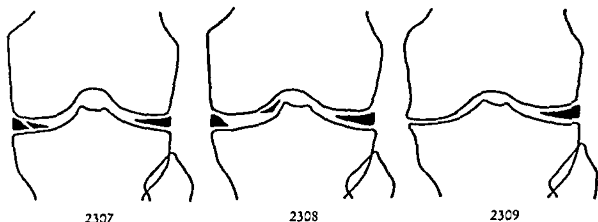


Fig 2307—Typical course of a longitudinal tear running from a point near the capsule downwards and towards the middle of the joint

Fig 2308 Displacement of the separated portion of the meniscus into the middle of the joint The base of the meniscus has remained intact

Fig 2309—After removal of the entire meniscus and not only the torn portion the medial joint space has become narrow as a result of erosion of the cartilage due to absence of the wedge of fibrocartilage

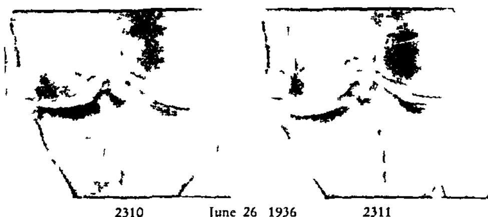


Fig 2310—Knee joint of a 28 year old football player whose entire meniscus not only the torn portion was removed at another hospital four years ago The medial joint space is markedly narrowed Arthrotic marginal exostoses at femur and tibia Lateral subluxation of the tibia Pain in the knee Range of motion 180° to 60°

Fig 2311—Comparison picture re fig 2310 in held abduction The medial joint space can be opened to normal width The narrow lateral joint space is a sign that the lateral articular cartilage has also been damaged

dressing is applied from the web of the toes to the knee (see p 1514) An elastic bandage is wound around the knee which is removed at night Usually on the eleventh day the patients are discharged from hospital

Exercises Active toe and ankle motion, through full range is supervised by the surgeon on rounds each day beginning with the first day Formerly we initiated quadriceps exercises on the sixth day At present we leave the leg

Positioning the Leg The leg is placed on a Braun splint with the fore foot suspended with an Unna's paste dressing, adhesive plaster (see Vol II/fig 1610) or a triangular bandage (fig 2641) to prevent heel cord shortening and to secure the leg against rotation Formerly we used to immobilize the knee extended on a Cramer wire splint It is much simpler and more agreeable for the patient to place the leg on a Braun splint

Report on the Operation Immediately after operation the operative findings should be dictated so that no essential details are forgotten The following points are included type of anesthesia, tourniquet, positioning of





2305 2306

Figs 2305 2306 — Oblique incision at the medial aspect of the knee joint to avoid damage to the saphenous nerve The transverse incision through the fibrous capsule is closed with six thin silk sutures Below the incision the cutaneous nerve can be seen running parallel with the skin incision

the leg incisions through the skin and the capsule, amount and color of the joint effusion, appearance of the synovial membrane of the fat pad and the meniscus, of the anterior cruciate ligament, the visible parts of the articular cartilage, as well as the form and appearance of the tear and the removed portion of the meniscus kind of excision kind of wound closure, application of the pressure bandage and post operative position of the leg The form of the tear is also recorded by a sketch

Loosening the Pressure Bandage If the patient complains of pain at night both forefingers are inserted underneath the bandage to feel whether it is too tight If this is the case it is at once divided throughout its full length The pain as a rule subsides immediately A new elastic bandage is then applied a

The prescription of crutches is useless My former assistant Ehalt[1] has described two cases in which this was done

Case 1 A 20 year old farmhand fell and sustained an injury of the right knee joint At first he was treated for a few weeks by the panel doctor As irradiation and compresses yielded no success and the pain in the knee persisted the patient was sent to a surgeon who diagnosed an injury to the meniscus or articular cartilage An X ray was negative The surgeon prescribed *two crutches* to be supplied by the health insurance The patient was to use the crutches to relieve the meniscus from pressure The surgeon stated that the lesion to the meniscus or articular cartilage would probably heal slowly of course owing to the bad nutrition of the meniscus and the cartilage He went on to say that if things did not improve noticeably within four weeks arthrotomy and removal of the meniscus or the cartilage necrotic by then would be indicated An operation would be premature at that time as spontaneous healing might occur and an error in the diagnosis was possible though unlikely

The crutches were provided by the health insurance We do not know whether the patient used them or not The expected improvement did not take place Six weeks later the knee joint was opened through a medial para patellar incision (after Payr) by that surgeon The visible articular cartilage was completely normal the anterior portion of the medial meniscus was split the split part was removed Uneventful healing Afterwards the patient persistently complained of pain and said he could only walk for half an hour To his neighbor he said how pleased he was that he had been operated on Now he had an excuse for falling ill as often as he liked since a piece was missing from his knee

We saw the patient one and a half years after operation Again he had been off work for four weeks He said he had stumbled and twisted his knee He complained of pain at the lateral side of the knee We were asked whether there was an injury to the lateral meniscus and whether operation was necessary

The patient was in excellent general condition he walked with an exaggerated limp but was able to run down a long corridor after several attempts There was no muscular atrophy the operational scar showed no reaction and was well movable The range of motion was the same on both sides there was no effusion in the joint, no pain on abduction or adduction Point tenderness was announced irregularly especially when his attention was diverted We warned against an operation and further treatment by the health insurance

Case 2 A 26 year old merchant felt a sharp pain in his left knee while starting up his motor cycle Afterwards he could neither fully extend nor flex the knee On the next day he went to a hospital where an injury to the meniscus was diagnosed A plaster cast was applied for six weeks and he was told to use *two crutches* to avoid weight bearing The man who was greatly interested in regaining the normal capacity of his leg followed this advice most carefully although it greatly handicapped him in pursuing his occupation Five weeks after the injury he came to our hospital with the plaster cast and the crutches We removed the plaster and took away the crutches telling the patient that they had been very useful but that he would now be able to do without them In such cases one has to be very careful not to discredit the surgeon who originally treated the patient After removal of the plaster there were no signs of an injury to the meniscus We applied an Unna s paste dressing in which he could resume his professional work and engage in sport Four months later he slipped on smooth ice and arrived with limitation of extension of the knee Examination ascertained an injury to the meniscus A bucket handle tear was found at operation and the torn part removed Healing was uneventful Four weeks after the injury he was again fully able to work A short time later he took up his sports again

Massage and passive motion irritate the joint and delay improvement They often cause effusion in the joint and thickening of the capsule

Diathermy, hot air and irradiation with lamps of different colors are time-filling but actually superfluous measures which as a rule do not disturb the

[1] Ehalt Meniscuslasion und Verordnung von Krucken Munchen med Wchnschr *19* 709 1934

lying on the Braun splint or a pillow for 10 days After application of the Unna s paste dressing and the elastic bandage the patients are allowed up In the first few hours they usually walk with the help of two canes, later on without a cane Most patients can flex the knee to the right angle at the first attempt and have full extension In teenage patients mobility is usually completely free two to three weeks later, *in older individuals four to six weeks later*

We tell all patients to walk only as long as they feel no pain They should not overstrain themselves in the first few days and should not attempt to flex their knees forcefully They should also abstain from massage, forceful motion and overheating Their knee should not be touched by anyone else The patients report every week so that we can observe whether the knee has become swollen due to overstraining Most patients can walk without pain and for an unlimited period of time three to four weeks after operation *The patients recover in the shortest time if they are left to themselves and if we only see to it that they do not walk too much within the first few days*

If inspite of this an effusion occurs the patient is put to bed until it has disappeared under slight compression of rubber sponges Aspiration of the fluid is not necessary Chronic postoperative joint effusion requiring X ray therapy or total synovectomy never occurs without forcible after-treatment

Hot air and irradiation are not used as they often cause effusions

Massage and passive movements are not used on principle, because they irritate the joint and cause effusions What can be gained by exercises begun as early as the second to the fourth day after operation? Has anyone seen a stiffened knee after a meniscus operation in which the indication was correct, technique proper and in which forcible after-treatment was avoided? Exercises begun too early may lead to infection The result of this will be a severely or completely stiffened knee, if not loss of the leg or death

No exercise should cause pain The case history on page 1606 shows how much harm can be done to an operated knee by forcible movements, and how soon the full range of motion is regained without them

Duration of Treatment Young patients usually are fit for every kind of work after four to five weeks and can take up all sports after two to three months In older patients this takes longer If long incisions are made instead of short ones, it sometimes takes three to four months to regain normal range of motion

Unsuitable Measures in Conservative Treatment of Injuries to the Meniscus

Immobilization with Plaster Casts Since an extensive tear of the meniscus and especially a pedunculated tag or a bucket handle tear (fig 2290) can never heal by union, it is useless to immobilize a knee joint for one to two months The advocates of conservative treatment have given no proof by pneumoradiograms that their original diagnosis was correct and that a tear of the meniscus had united at the time the plaster was removed An intact meniscus loosened from the capsule (figs 2284 a—f, 2301—2304 and 2345) will, however, unite if the knee is immobilized for the main injury (rupture of collateral ligament or fracture of the bone) over a long enough period

developed and rarely shows the full height and width of the original meniscus (fig 2312 a) Moreover, this substitute tissue is less resistant than the real meniscus, even though it will sometimes assume its shape For this reason it is reported that after total extirpation tears of the "regenerate" occur in 4 to 5% of the cases All attempts to prevent the development of such a regenerate, alleged to be superfluous, but in actual fact urgently needed, are doomed to failure, even if the most radical measures are taken to stop it It will therefore be more expedient to leave the uninjured base of the meniscus where it is, since statistics have shown that it is more resistant to pressure and less prone to secondary tears than the regenerate'

Many reports on secondary tears of the posterior horn are found in the literature The assumption is justified that a portion of the meniscus that had been loose already at the time of the first operation was overlooked and thus remained untouched

Some remove the whole meniscus if signs of degeneration are seen, because they believe that every degenerated meniscus will cause trouble If this were true most of the people over 40 years of age would have meniscus symptoms, since recent research has shown that the menisci are usually degenerated by that age If the advocates of total extirpation of the meniscus were completely convinced of the malignancy of degeneration, they would be compelled to remove, even without an injury, all four menisci in every person over 50 years of age We have the impression that the significance of a tear of the meniscus is greatly overestimated and the importance of the menisci as necessary parts of the knee joint is vastly underrated A torn meniscus with repeated impingement is a significant disability The separated portion can easily be removed But if it is left untouched, it will usually cause less trouble in future than the complete loss of a meniscus The meniscus should therefore never be removed in toto The meniscus must not be compared with the appendix, the presence of which may lead to a very dangerous inflammation at any time and whose absence causes no disturbance Moreover, a meniscus can never grow malignant

We believe that the menisci are very important parts of the knee joint and should not be sacrificed unnecessarily They form wedge-shaped rings lying between the rounded femoral and tibial articular surfaces whose peripheral parts are not in contact Aided by their incredible mobility and adaptability they fill the marginal space between the two bones in every position of the joint, thus contributing to its stability They also act as buffers absorbing excessive shocks, a fact that is denied by those who remove them on principle

In a genuine injury of the meniscus occurring within the fibrocartilaginous tissue the base of the wedge always remains intact (figs 2285—2296, 2300, 2307, 2308) and the mechanism of the joint is not significantly disturbed if the separated portion alone is removed

Total extirpation leads not only to 4 or 5% of tears in the 'regenerate' but also frequently to arthrotic changes (see pp 1608—1611) as late complications

The dispute whether the meniscus should be extirpated or only the torn portion removed, can be settled only in the following way X-rays of both knees in both planes are taken before operation in each case to decide whether

natural course of healing They become harmful if a necessary operation is delayed by them

Unsuitable Measures in Operative Treatment of Injuries to the Meniscus

Unsuitable Incisions All incisions dividing the collateral ligaments or the extensor apparatus or those detaching the tibial tubercle or other ligamentous attachments, and all approaches with oblique or longitudinal splitting of the patella damage the joint The big S-curved para patellar incision according to Payr, delays healing by twice the necessary time and sometimes causes permanent disturbances

Total Extirpation of the Meniscus Many surgeons recommend the complete excision of the entire meniscus in every tear of the meniscus and in every arthrotomy for suspected tear of the meniscus, i e, extirpation of the entire meniscus as if it were a malignant tumor, even if the meniscus shows no tear and no signs of degeneration Some perform this extirpation with "fire and sword as they excise the entire meniscus and destroy the adjacent tissue by electrocautery They argue that after excision of merely the torn part a secondary tear may occur in the remaining part They report 1 to 2% of secondary tearing among the patients treated with partial excision Weissbach has observed only *one secondary tear among 500 patients treated with* partial excision We have observed seven secondary tears among our 1000 cases treated exclusively with partial excision But here the objection might be raised that patients with recurrent locking are likely to consult another surgeon and thus remain unknown to the first However, Streli followed up our 82 surviving patients of the years 1926 to 1933 after a lapse of 18 to 25 years Of these patients not a single one had been operated on for a recurrent tear, neither in our hospital nor elsewhere (see page 1620)

Cause and Susceptability to Tearing of Regenerates of Meniscus According to Fick[1] the height (thickness) of the base of the medial meniscus *measures 1 5 to 3 5 mm in front 5 to 6 5 mm in the middle and 6 to 7 5 mm* at the back The width is 4 to 5 mm in front and 15 to 17 mm at the back The height (thickness) of the base of the lateral meniscus is 4 5 to 6 mm Its width is 13 mm In total extirpation of a meniscus a gap is produced between the femoral and tibial condyles corresponding in size to the above mentioned measurements of the menisci If this gap continues to exist without the buffer effect of the meniscus the articular cartilage will be compressed and ground out in its center as can be seen in some cases in which the joint space has become narrower and narrower Generally however the parameniscal fatty and connective tissue enters this gap more or less deeply, where it is exposed to pressure and within a few months transformed to coarse fibrous tissue but not cartilage This is the so-called regeneration of a meniscus However, the process is not due to an incredible power of regeneration on the part of the meniscus It is a purely mechanical process in the course of which a gap in the tissue is filled by surrounding tissue The regenerate is often incompletely

[1] Fick R Handbuch der Anatomie und Mechanik der Gelenke Jena Fischer 1904 Vol 1 p 356

time The hyperemic treatment with the change of warm and cold and the exercises are continued In the cases of severe congestion under water massage With this treatment flexion reaches the right angle usually at the end of the third week The patient still goes on crutches Sometimes an acute collapse of the capillaries occurs and a badly irritated knee results, severe atrophy of the muscles, severe congestion of the lower leg and acute decalcification of the bones ensue Further exercise leads to increase of the muscular atrophy Secondary hemorrhage, fibrinous exudate and fibrosis frequently lead to severe limitation of flexion The knee is then manipulated under general anesthesia Treatment may last months in these cases

If no exercises are carried out, as is our routine, if the patients are left to themselves and told to omit everything that causes pain, none of the circulatory disturbances due to forced physiotherapy as described by Groh (congestion after three days' exercises, acute collapse of the capillaries, severe muscular atrophy, acute decalcification of bones, limitation of motion by fibrosis) will occur

Cause, Prevention and Treatment of Early Complications After Operative Treatment and Intense After-treatment of Injuries to the Meniscus

The early complications following operative treatment and especially intense after-treatment of injuries to the meniscus are

1 Anesthesia due to division of the geniculate branch of the saphenous nerve 2 Severe effusions in the joint 3 Severe muscle atrophy 4 Considerable congestion of the lower leg 5 Acute decalcification 6 Infection with empyema, ankylosis, amputation and death

Re 1 Division of the geniculate branch of the saphenous nerve can be avoided by use of the proper incision

Re 2 Severe effusion in the joint will form only when the whole meniscus is excised or early energetic passive motion is carried out If only the torn portion is removed and if all after-treatment is omitted, joint effusions will rarely occur If they occur they will remain slight and soon disappear through immobilization

Re 3—5 Severe muscular atrophy, severe congestion of the lower leg and acute decalcification are the consequences of sudden circulatory disturbances They are observed only after intense after-treatment, as described by Groh (p 1606) This condition is called an irritable or sensitive knee If no after-treatment is carried out and the sensitive knee is not irritated, these disturbances will not occur

Re 6 Infection of the joint with empyema and ankylosis is rare Amputation and death due to septicemia are quite exceptional Up to now we have had no case of a joint infection The best way to prevent it is partial, instead of total excision of the meniscus With this method the operation can be performed within eight to ten minutes, the joint remains open for only a few minutes, and the wound surfaces are small According to Groh intense physiotherapy may also lead to a Superinfekt This condition is treated with

they are normal or show changes The excised menisci must be preserved to enable their examination for size and shape at the time of the follow up All these patients should be re examined physically and radiologically after 5, 10, 15, 20, 25 years and later If it can be shown that arthrotic changes as in figs 2310 2311, with corresponding complaints, occur frequently in the cases treated with complete removal of the meniscus, whereas arthrotic changes do not normally occur in the cases of partial excision, the latter method has been proved correct Streli has meanwhile re examined our 82 surviving patients of the years 1926 to 1933 after a follow up time of 18 to 25 years and has found that after excision of only the loose portion arthrotic changes have only developed where abnormal changes of the joint had already been present before the operation, where severe injuries were sustained at a later time or where arthrosis due to constitutional factors also developed in the non injured knee

Pfab ascertained in animal experiments that arthrotic changes always developed after total removal of the meniscus

Unsuitable Exercises

Massage and passive movements always damage an injured knee joint and healing is unduly delayed This also occurs with overheating The following case history shows how it took a young man a whole year to regain motion of the knee joint after treatment with massage and passive movements and how the joint became freely movable seven weeks after a second operation without massage and passive stretching

Case History A 17 year old man (born in 1900) who served as an army volunteer sustained an injury to the meniscus through a fall from a horse in 1917 He was treated by complete excision of the meniscus Thereafter massage and energetic passive movements which at times were so painful that he cried aloud and fainted several times On such days the knee became severely swollen A day of rest was then interposed For some weeks he walked with crutches then with a cane After four months he flexed the knee to a right angle Then he was discharged to a school where massage was continued Only after nine months could he take up light military duty and only after one year could he fully flex his knee In 1923 locking of the knee occurred and he felt a joint mouse It was removed operatively Post-operative rest in bed for three weeks Then again forceful massage and energetic passive movements by a nurse who however was not as strong as the masseur The movements caused considerable pain but he never fainted After two months he could flex the knee to a right angle and after six months the range of motion was free In 1940 again locking of the joint X rays revealed two joint mice which were removed in our hospital on August 30 1940 His leg was placed on a Braun splint for 10 days then he got up with an Unna s paste dressing and an elastic bandage On September 15th he went back to work as a merchant On the 23rd of September he was able to flex his knee to the right angle and on the 21st of October he showed a full range of motion even though or rather because his knee was never touched

An interesting plan of exercises was described by Groh [1] 14 days after the operation he begins with hyperemic measures by a change of warm and cold (hot air diathermy ice compresses) tourniquet for one to two minutes and at last hot fomentations To this are added accurately described exercises of the leg On the 16th day the patient is allowed up on crutches for the first

[1] Groh Zur Übungsbehandlung des operativ versorgten Kniegelenkes Zentralbl f Chir 65 2545—2553 1938

Time of Observation	1—5 Years	6—10 Years	11—15 Years	16—19 Years
Total Patients	16	11	6	2
X-rays Negative	15	6	2	0
Arthrotic Changes	1	5	4	2

In reference to partial excision of the meniscus, there are — as far as we know — only Kromer's (see p 1617) and Streli's (see p 1618) statistics on the relevant end results In 1935 Kromer re examined our first 111 cases after one to seven years Within this time no arthrotic changes were found Nor were arthrotic changes observed at a second examination in 1940, i e, six to twelve years after operation Of the 111 cases of Kromer's, Streli in 1951 re examined the 82 patients who survived and had not left Austria After a follow-up period of 18 to 25 years a clinical and radiologic re-examination was carried out Normal knee joints were found in 30 patients, sharpened condylar edges in 33 patients, lipping in 7 patients Arthrotic changes (12 cases) had developed only in those patients who had shown abnormal findings already before operation or had sustained a new injury after operation

The frequent occurrence of arthrotic changes after total extirpation is not surprising, since as a rule the "regenerated meniscus is not of high quality The newly grown substitute is usually smaller in width and height than the wedge which remains after partial excision Moreover, its elasticity is inferior If the meniscus has been completely removed from the joint and has only partly regenerated, a comparatively narrow strip of the femur rests on the tibia As a result, the articular cartilage is gradually worn down until a broad contact surface results The X-ray shows that the joint space becomes narrower, and marginal exostoses result from continuous irritation (figs 2310, 2311, 2312 b, c) Lateral instability supervenes in some cases as can be seen well in figure 2311 When such a joint is opened, the weight-bearing parts of the femoral condyles are sometimes found to be completely bared of cartilage, so that the bone can be seen

The most severe disturbances have been observed when the whole meniscus was removed in cases of rupture of the medial collateral ligament, and when massage and passive movements followed immediately Some of these joints became unstable and showed marginal exostoses as early as after one year After a few years the other leg also sometimes showed signs of damage due to excess stress Pain will not be felt at first during sports, but in the course of continuous hard work

We have been able to observe these occurrences in a great number of patients who were treated by total meniscectomy at different hospitals In our 1000 patients, however, in whom the wedge-shaped base of the meniscus was retained in every case, marginal exostoses have developed — after a follow-up period of 20 years — only in those patients in whom abnormal findings of the knee joints were present before operation or who had met with severe accidents later on

Re 4 In some cases we found loose bodies that have became wedged in the joint after total meniscectomy After partial excision of the meniscus we have never observed loose bodies

incision of the suprapatellar pouch, in some cases with irrigation with antiseptics and a big hip plaster spica which includes the sound thigh

Cause, Prevention and Treatment of Late Complications Following Operative Treatment and Intense After-treatment of Injuries to the Meniscus

Late complications after injuries to the meniscus are 1 Secondary tears 2 Limitation of rotation of the lower leg 3 Arthrotic changes 4 Formation of loose bodies 5 Muscle atrophy 6 Limitation of motion and pain

Re 1 The danger of a secondary tear is the argument put forward by the surgeons performing total exstirpation As described on pages 1604, 1605 complete avoidance of secondary tears cannot be achieved by this procedure Moreover, tears of the regenerated meniscus after total extirpation are more frequent than tears of the portion left behind after partial excision The best method of avoiding tears of a regenerated meniscus is to avoid total extirpation Regenerated menisci can then not develop, and if they are not present they cannot tear If secondary tears after either method occur in 1 to 4% of the cases, it is of little importance, since new locking of the joint can be treated by the relatively simple operation of partial excision of the meniscus

Re 2 Limitation of rotation of the lower leg has never occurred following partial resection and conservative after-treatment It results from forcible after treatment with massage, passive exercise, overheating and undercooling

Re 3 Arthrotic changes are of great importance In some cases of total extirpation they can already be seen in the X-ray after one year The number of these cases increases from year to year until after 15 years arthrotic changes are found in 50 to 100% After partial excision, on the other hand, they are not found at all or in a small degree only, unless arthrotic changes were present in the knee already before operation or the knee has sustained a new severe injury after the operation

Efskind [1] has re-examined 32 patients after 1 to 9 years 19 patients 1 to 5 years after the meniscectomy and 13 patients 5—9 years after the operation Seven patients of the first group and 12 patients of the second group showed evidence of arthrosis on X-ray

Übermuth re examined 55 patients after 3 to 15 years and found arthrotic changes in 18 (30%) patients

Hübner [3] re-examined 35 patients 1 to 15 years after operation and found arthrotic changes in half the patients

Nitter [4] has given the most accurate statistical evidence

He re-examined 35 patients 1 to 19 years after total extirpation and found that the number of patients showing arthrotic changes was very small within the first five years but later increased steadily

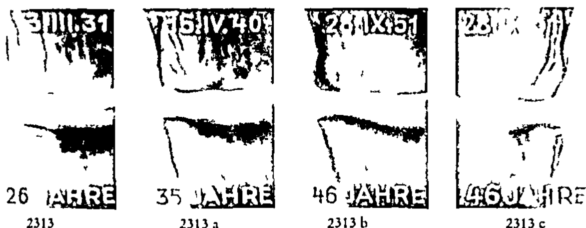
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1 Efskind Über Meniscusschaden Acta chir scand *82* 499—528 1939

2 Übermuth Meniscusexstirpation Regeneration und Arthrosis deformans Der Chirurg *13* 329—334 1941

3 Hübner Meniscusoperation und Arthrosis deformans Mschr f Unfallheilk *50* 1—5 1943

4 Nitter Arthrosis in the Knee after Meniscectomy Acta chir scand. *90* 483—494 1944



2313 2313 a 2313 b 2313 c

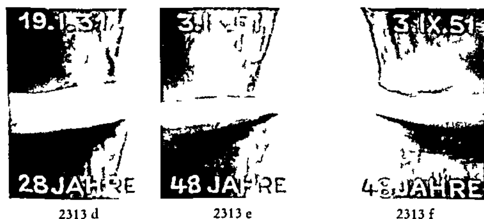
Figs 2313–2313 c —Development of marginal exostoses in a knee joint the X ray of which was normal before operation after partial excision for a longitudinal tear of the medial meniscus in a 26 year laborer who slipped at work and fell X rays of the medial joint space of both knees in natural size

Fig 2313 —Both condyles of the left knee show normal contours before operation

Fig 2313 a —Nine years later the margins of the condyles are no longer round but sharp edged

Fig 2313 b —20 years after operation there is slight lipping at the tibial margin

Fig 2313 c —The lipping of the non injured tibia is slightly more pronounced than of the injured tibia The femoral condyle shows a normal round edge



2313 d 2313 e 2313 f

Figs 2313 d–f —Development of a severe marginal exostosis in the knee of a 28 year old mason who fell from a street car Even before the partial excision of a bucket handle the knee had been damaged by a 5 year old rupture of the anterior cruciate ligament The pre-operative X ray already showed sharpened rather than round edges of the condyles

Fig 2313 d —Sharpened edges of both condyles present before operation

Fig 2313 e —20 years after operation the tibia shows severe lipping and there is a marginal exostosis at the femur Narrowed joint space

Fig 2313 f —The condylar margins are also sharpened on the non operated side The width of the joint space is about the same as on the operated side

Re 5 All cases with severe marginal exostoses develop muscular atrophy of from 1 to 4 cm This is especially marked at the vastus medialis

Re 6 Advancing arthrotic changes will be followed by limitation of motion and pain mainly when walking downhill

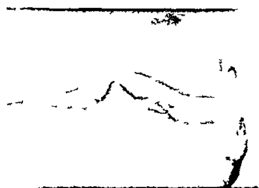




2312 January 21 1939 2312 a November 24 1954

Fig 2312 —Lateral meniscus with transverse tear at the middle from a 22 year old man in whom total exstirpation of the entire lateral meniscus with the fat pad was carried out at another hospital In the anterior part can be seen where the meniscus forceps had been applied Severe effusions and limitation of motion necessitated treatment for six months Arthrotic changes were visible in the joint as early as one year after operation Circumference of thigh 3 cm less than on the non-operated side

Fig 2312 a – Left Regenerated meniscus after total extirpation eight months previously Right Normal meniscus for comparison from the knee of a corpse according to Schäfer [1] Most regenerated menisci are even thinner and narrower and only seldom wider





2312 b August 27 1951 2312 c, September 11 1950

Fig 2312 b —X ray of the knee joint of a 38 year old woman whose entire medial meniscus was extirpated at another hospital eleven years ago Marginal exostoses at the tibia and femur The medial joint space is severely narrowed Lateral subluxation of the tibial head Walks with pain

Fig 2312 c —X ray of the knee joint of a 43 year old football player whose entire lateral meniscus was extirpated at another hospital 22 years previously Two years later he had to give up playing football Moderately large marginal exostoses mainly at the lateral femoral and tibial condyles two loose joint bodies Because of locking we removed them through an anterior and a posterior incision At operation the anterior and middle portions of the meniscus were missing The articular cartilage of the lateral femoral condyle was largely destroyed

1 Schäfer Zur Rearthrotomie des Kniegelenkes zugleich ein Beitrag zur Regeneration des Meniscus Zentralbl f Chir 78 1048 1953

injury should be acknowledged as an occupational accident and not rejected simply because the microscopic examination has revealed degeneration of the meniscus Furthermore, after a tear of a sound meniscus, signs of degeneration will develop in the separated portion after some time Schaer[1] demonstrates this in figures 53 and 54 of his book

In *summary* it must be stated that of the postulates which are made with regard to recognition of a torn meniscus as an industrial or occupational accident generally, none are met, for

1 As a rule the violence acts indirectly, not directly
2 The acting force is usually slight A quick rotation with the knee slightly flexed is sufficient
3 Pain is usually slight at the first tear, it will be severe when impingement occurs later on
4 Work is often continued
5 Therefore as a rule no doctor is called
6 The effusion is usually small and not hemorrhagic, so that often no aspiration is necessary
7 In a genuine tear of the meniscus the joint fluid is usually clear or only slightly blood-stained If blood is found in the joint at operation, it comes from an injury to the capsule or bone
8 Microscopic examination shows signs of degeneration from the 25th year on If a portion of the meniscus has been separated by a longitudinal tear, it will degenerate after a few weeks

As these postulates were known to many insured persons, they and their fellow-workers gave false evidence on the circumstances of their injuries, maintaining that they had been caused by direct violence Many of them stopped working even if the injury was only slight, because those willing to work were rejected by insurance authorities But neither false evidence, nor stopping work nor immediate consultation of a doctor helped to get the accident recognized as an industrial accident, because in a genuine tear in the fibrocartilaginous tissue of the meniscus, bloody effusion cannot be found at aspiration nor at early operation And even though effusion occurred occasionally, the case could still be rejected in the presence of histological degeneration

I have spoken with some experts about these postulates and was astonished to learn that meniscus tears could not be acknowledged as industrial accidents because this would cost the insurance carriers millions every year

In my opinion it is wrong to administer "justice in accordance with the postulates quoted above because they are wrong

In Austria the tear of a meniscus is recognized as an insured occupational accident if evidence can be produced to show that it occurred during work Suits arising from meniscus injuries are therefore practically unknown in our courts If only partial resection is performed instead of total extirpation and if all forms of after treatment especially painful ones, are avoided, the injury will generally heal without permanently impairing the patient s ability to earn

[1] Schaer Der Meniscusschaden Leipzig Thieme 1938

Disability Evaluation of Injuries to the Menisci and Recognition as an Insured Occupational Accident

Whereas formerly, every tear of the meniscus occurring in an insured person during working hours was acknowledged as an insured industrial or occupational accident, nowadays many reject those cases in which histological examination shows signs of degeneration

The following postulates have been made for the recognition of an injury of the meniscus as an occupational accident "A considerable violence must have hit the knee directly The patient must at once show signs of a serious injury such as severe pain, inability to bear weight on the leg, discontinuance of work, consultation with a doctor The effusion withdrawn by aspiration or seen at operation must prove hemorrhagic The microscopic examination must not show any signs of pronounced degeneration

Most of these conditions are usually fulfilled in severe injuries of the collateral or cruciate ligaments or in tearing of the capsule, where the meniscus is not damaged but only loosened from its attachment to a varying degree (figs 2284 a—f, 2301—2304, 2345) On the other hand, genuine injuries of the meniscus do not meet these postulates since they are usually caused by indirect violence and rarely show bloody effusion If, as an exception to the rule, the body of the meniscus is injured by direct violence, this injury is insignificant as compared to the associated injuries of the ligaments and capsule

Direct Violence The genuine tear of the meniscus i e, within its fibrocartilaginous body, usually results from indirect, not from direct violence, viz, by a sudden, unexpected rotation of the more or less flexed femur on the fixed tibia in a moment when the knee joint bears the full weight of the body or even additional weight This rotation is usually caused by unexpected slipping or stumbling or by a jump If a football player s meniscus gets torn by an impact of another man s knee, direct violence is not the cause of the tear, in general but the subsequent sudden rotational strain

Pain is always present in a tearing of the meniscus, but normally, only the pain in the impinged bucket handle cases is so severe as to make the patient discontinue his work at once Sometimes a case of impingement can be released by shaking the joint or by traction on the leg Subsequent pain is frequently so slight as to allow continuation of walking or working Thus, a doctor is not consulted in all cases

A bloody effusion is generally absent in a tear of the body of the meniscus, even in purely traumatic cases with microscopically sound cartilage as is proven by our experience of more than 1200 cases the greater part of which were operated on within the first few days after the accident Only in exceptional cases was the usual slight serous effusion somewhat blood stained This was caused by a concomitant injury to the synovial membrane Small spots of hemorrhage, however are seen on the ruptured surfaces in the case of a recent tear of the meniscus

In reference to *degeneration* it must be emphasized that a knee joint with a degenerated meniscus may meet with a severe accident In such a case the

26 Have I avoided excision of a normal meniscus?
27 Have I avoided ligature of vessels?
28 Have I extended the knee for the suture of the capsule and the skin?
29 Have I overlapped the fascia in the case of a rupture of the cruciate ligament?
30 Have I applied a pressure bandage which also covers the suprapatellar pouch?
31 Have I removed the tourniquet only after application of the pressure bandage?
32 Have I dictated the exact findings immediately after the end of the operation?
33 Have I elevated the patient's leg on a Braun splint or a pillow?
34 Have I split the pressure bandage on the first evening if pain has set in?
35 Have toes and ankle joint been actively moved through their full range from the first day on?
36 On the tenth day has an Unna's paste dressing been applied from the web of the toes to the knee, and an elastic bandage round the knee?
37 Have I allowed the patient up 10 days after operation?
38 Have I told the patient he may do all forms of exercise which do not cause pain, but that he should avoid overstrain during the first few days?
39 Have I kept the patient in bed and applied a pressure bandage with foam-rubber if an effusion has developed?
40 Have I omitted any kind of after-treatment such as application of warmth or gymnastics?
41 *Have I warned the patient against massage and passive motion?*

End-results Following Operation of Injuries to the Meniscus

Within the 28 years from 1926 to 1953 at the Vienna Accident Hospital we operated upon 1078 knee joints for suspected injury of the meniscus. In 1012 (93.9%) cases we found a tear of the meniscus and removed the torn portion. The intact base of the meniscus was always retained. In 66 (6.1%) cases we found no tear of the meniscus, but in 44 of these cases other causes of the complaints were detected. In seven cases free cartilaginous joint bodies, which showed no trace on X-ray were found. In ten cases ruptures of the cruciate ligaments were encountered, the distal stumps of which were interposed between the condyles. Nine times we found pedunculated fatty villi, twice pedunculated capsular polypi, eight times we detected a synovitis, three times a hemarthrosis without visible cause, once a capsular rent, and once we suspected tuberculous arthritis. In 22 cases the joint cavity revealed neither a tear of the meniscus nor any other abnormal findings.

Among the 1012 patients with torn menisci 830 (82%) were males and 182 (18%) were females.

Of the tears of the meniscus 908 (89.5%) were located medially and 104 (10.5%) laterally.

The youngest male patient was 15, the oldest 69 years of age. The youngest female patient was 14 and the oldest 68. These four patients had bucket handle tears. In the oldest male patient and in the oldest female patient

his living. Among our cases of working accidents followed up by Streli for 19 to 25 years there is not a single one receiving a permanent disability pension.

We have no experience with meniscus injuries sustained by miners. Due to the efforts of Andreesen, Burkle de la Camp, Groh and others, these injuries, when "occurring in miners after a minimum of three years regular work under ground," are now acknowledged as an occupational disease (cf. 5th Regulation concerning occupational diseases, dated 26 July 1952, Austrian BGB I, p. 395, No. 26).

Questions We Should Ask Ourselves in Order to Avoid Failures In Examining and Treating Injuries of the Meniscus

1. Have I obtained an exact history of the origin of the injury?
2. Have I asked whether the knee had been injured previously?
3. Have I examined the knee for swelling?
4. Have I examined the knee for its range of active extension and flexion?
5. Has pain been felt on attempting hyperextension?
6. Has abduction or adduction of the knee elicited pain?
7. Have I examined the knee for pain on rotation?
8. Have I examined the knee for localized tenderness over the joint space with and without rotation?
9. Have I palpated the edges of the tibial and femoral condyles for tenderness?
10. Have I taken anterior and lateral X-rays of both knees?
11. Have I omitted plaster immobilization in the case of a definite diagnosis?
12. Have I advised early operation in the case of a definite diagnosis?
13. Have I, before operation, examined the skin of the knee and all the body to exclude any signs of inflammation of the skin?
14. Have I also searched for other inflammatory changes (tonsillitis, etc.)?
15. Have I omitted alcohol compresses or other skin antiseptics before operation?
16. Has the skin not been shaved until just before operation?
17. Has the leg been exanguinated and the tourniquet been applied after the beginning of the anesthesia?
18. Have I avoided big longitudinal or transverse incisions?
19. Have I used a 5—6 cm. long oblique incision to preserve the geniculate branch of the saphenous nerve?
20. Have I incised the fibrous and synovial capsule with a 4—5 cm. long transverse incision 2 cm. cranial to the edge of the tibial condyle to avoid cutting into the base of the meniscus?
21. Have I avoided incising the fat pad as it bleeds profusely?
22. Have I forced out the joint effusion by pressure on the popliteal space, and sponged it out?
23. Have I searched for hemorrhagic spots on the surfaces of the tear in the case of a recent injury?
24. Have I excised only the separated portion of the meniscus and preserved the base of the meniscus (partial excision of the meniscus)?
25. Have I avoided total extirpation of the meniscus since this will usually cause later arthrotic changes?

"Fair" was used to designate those with more severe symptoms and measurable atrophy of the quadriceps, crepitation of the joint effusion on strains and perceptible limitation of motion

The end-result was classified as "poor," when the patient suffered from severe complaints, had considerable limitation of knee motion, and absence of lateral stability

None of the patients was classified in group three or four, i e, in no case was there noticeable muscular atrophy crepitation on flexion and extension, or instability of the joint

Of the 110 patients 91 (84%) had excellent results,
19 (16%) had good results

These end results are not equally distributed among insured and uninsured patient because

of 51 uninsured patients there were 47 (92%) excellent results,
and 4 (8%) good results

Among 59 insured patients there were 44 (75%) excellent results
and 15 (25%) good results

As the difference between excellent and good end results was based solely on subjective complaints it is understandable that insured persons who were unemployed at the time complained of symptoms, hoping to get some compensation

Compensation Of the 60 insured cases of meniscus injury, 13 were not acknowledged as occupational accidents Among the 47 acknowledged occupational accidents only one patient drew a permanent pension all others were without compensation The patient with the permanent pension is a 47 year old coachman There are no abnormal findings in the operated knee, but he suffers from varicose veins varicose eczema, bilateral severe flat feet and halluces valgi It is therefore credible that he has trouble with his legs but not due to the meniscus injury

In the second group of 189 meniscus injuries of the years 1934—1939 there were 60 insured occupational accidents None of them draws a permanent disability compensation

It should be emphasized that the disability evaluation was not made by us at that time, but by other surgeons

In 1940 we re-examined all traceable patients for a second time and took X rays of both knees in all cases No patient had developed arthrotic changes, and if such changes had been present before operation, they had not become worse

In 1951 Streli with infinite patience re examined for a third time the 82 surviving and still traceable patients of Kromer s 111 cases, after a follow-up period of 18 to 25 years 20 had died, were killed in the war or were missing 9 had gone abroad He could personally re-examine 80 patients and obtained exact reports of clinical examination and X-rays of the two remaining patients X rays of both knees were taken in all 82 cases

Total Re examined Patients	82 (76 males 6 females)
With Disability Insurance	57 (56 males 1 female)
Uninsured Patients	25 (20 males 5 females)

locking had occurred for more than 20 years The oldest female patient, at re-examination six years after the operation at an age of 74, had a range of motion of 175° to 65° as against 175° to 55° on the non-operated knee

Among the 1012 cases there were 564 (55 7%) bucket-handle tears, 91 (9 0%) longitudinal tears from the anterior to the posterior horn, 26 (2 6%) longitudinal tears in the anterior horn, 77 (7 6%) longitudinal tears in the middle portion of the meniscus, 53 (5 2%) longitudinal tears in the posterior horn, 39 (3 9%) pedunculated tags of the anterior horn, 38 (3 8%) pedunculated tags of the middle portion of the meniscus, 49 (4 8%) pedunculated tags of the posterior horn, 75 (7 4%) showed transverse and longitudinal tears One patient had a tear of the medial and the lateral meniscus From the great number of the bucket handle tears it can be seen that we operate only when definite signs are present

The first 111 cases of the years 1926 to 1933 were published by Kromer[1] after a follow up period of 1—7 years, in 1935 In 1940 Benkovich re examined all patients he was able to trace among the 111 patients of the years 1926 to 1933, and the 189 patients of the years 1934 to 1939 after a follow-up period of 2 to 15 years In 1951 Streli[2] re-examined the 82 surviving and traceable patients of the years 1926 to 1933 after a follow-up period of 18 to 25 years, and also the 723 patients of the years 1934 to 1949

Of the first 111 cases, reviewed by Kromer in 1935, one patient died from another disease four years after operation The remaining 110 patients were evaluated not only from the case histories, but 108 patients of these 110 were also personally re-examined by Kromer after a follow-up period of 1 to 7 years Of the last two patients who lived over 100 km away, reliable reports had been obtained by well-known physicians Both patients were without complaints

Total Patients	111 (98 Males 13 Females)
Number Insured Against Accidents	60 (59 Males 1 Female)
Not Insured	51 (39 Males 12 Females)

Average Duration of Treatment	
Insured Patients	48 Days
Non insured Patients	33 Days

End-results The results were divided into four groups classified as excellent, good, fair, poor

Excellent applied to those patients who showed normal objective findings of the knee on physical examination and had no subjective complaints

Good applied to those patients who had good function of the knee i e with range of active motion of from 180° to at least 70°, with no noticeable muscular atrophy but who at times had slight pain especially during change of weather

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1 Kromer Meniscusoperation und Unfallversicherung Arch orth u Unfall Chir 35 526—543 1935

2 Streli Spatergebnisse nach partieller Meniscusresektion bei 82 Fallen welche 18—25 Jahre nach der Operation nachuntersucht wurden Der Chirurg 26 97—103 1955

In one case the operated knee showed lipping as in figure 2313 e, and the non-operated knee had sharpened edges as in figures 2313 a—d

Three cases showed arthrotic changes as shown in figure 2310 on the non-operated knee, whereas the operated knee was normal

Of two cases, in whom the medial meniscus of the other knee was also operated on later, one case showed sharp edges on both knees as in figures 2313 a—d whereas the other one showed sharper edges on the knee which had been operated on later

Thus, among these 61 cases no changes attributable to partial excision of the meniscus were observed in 52 (85 25%) cases

"Good" Cases Of the 20 "good" cases only 10 patients complained of *subjective symptoms* The other 10 patients were asymptomatic

Overweight Among the 20 "good" results 17 patients had an average overweight of 15 Kg The most was overweight of 45 Kg, namely, 105 Kg with a height of 160 cm

Sensory disturbances were found in three of the 20 "good" cases

Mobility Among the 20 "good" cases eleven had a full range of motion of the knee One patient whose leg was later amputated below the knee for an open fracture of the lower leg had a range of motion of only 160° to 90° Six patients had full flexion, but extension was limited by 5° Five patients had limited flexion, i e, one patient could flex the knee to only 80°, the others to 70° or farther

Pre-operative Changes Of the 20 "good" cases in twelve patients various injuries or diseases of the operated knee were already present before the operation, such as injuries of the collateral or cruciate ligaments, osteochondritis dissecans, arthrotic changes and damage to the cartilage Only eight patients had a normal joint before operation

Injuries Sustained After Operation Three patients of the 20 "good" cases sustained severe injuries after the operation, viz, a lodging gunshot wound, a through-and-through gunshot wound of the tibial head, and an open fracture of both bones of the lower leg with subsequent below-knee amputation

X-ray Findings of the "Good" Cases Four patients of the 20 "good" cases showed normal findings in both knees on re-examination (fig 2313)

Three cases showed sharpened edges of the condyles of the operated knee as in figures 2313 a—d

Lipping as in figures 2313 e was present in two cases

Nine cases showed moderate arthrotic changes as in figure 2310

Two cases showed advanced arthrotic changes as in figure 2312 b

"Fair" Cases One case was graded "fair" Until seven years after operation he was excellent then he sustained a severe rupture of his ligaments He was treated elsewhere and his knee immobilized for too short a period His range of motion was from 180° to 65° as against 180° to 50° on the non operated side Muscular atrophy of 3 5 cm Severe arthrotic changes as in figure 2312 c with lateral subluxation

Summary The X-ray findings were as follows

1 30 cases were normal as in figure 2313

2 33 cases had sharpened edges of the condyles as in figures 2313 a—d

End-results In patients who had a normal knee joint before operation and who had sustained no new injury, the results were as good as at the time of re-examination in 1935 and 1940 Those patients, however, who had had previous damage (injuries of the collateral or cruciate ligaments, damaged cartilage, etc) or had sustained a new injury, showed slight deterioration as they had grown 19—25 years older, as some had met with new accidents to their operated knee, and many had gained considerable weight

Those patients were graded 'excellent who had a normal joint, normal muscles, who were asymptomatic and whose course since operation had been without event The X-ray was normal (fig 2313) or showed sharpened edges of the condyles (figs 2313 a—d) or a lipping of the articular margins (fig 2313 e), but no arthrotic marginal exostoses (fig 2311)

Those patients were graded "good' who had a range of active motion from full extension to a flexion angle of 70°, who had muscular atrophy of no more than 2 cm and complained of only minimal pain The X-ray showed no, or only slight, arthrotic changes as compared with the other knee

The patients graded fair either complained of more severe pain, or had a muscular atrophy of more than 2 cm , or a range of motion through less than 90°, severe arthrotic changes, or a loose joint

Of the 82 patients the result was 'excellent' in 61 (74 4%),
'good in 20 (24 4%),
fair" in 1 (1 2%)

Influence of the Incision The curved parapatellar incision (Payr) was used in five of the early cases Among these only one has an "excellent result, three are good and one is only fair Three of the five patients showed arthrotic changes The average duration of treatment was 127 2 days as against 48 and 33 days in the patients operated through the short oblique incision

X-ray Findings These were graded

1 normal findings (fig 2313)
2 edges of the condyles sharpened (figs 2313 a—d),
3 lipping (fig 2313 e),
4 moderate arthrotic changes (fig 2310),
5 advanced arthrotic changes (fig 2312 b)
6 severe arthrotic changes (fig 2312 c)

Between 1952 and 1954 I reviewed, with Streli, every series of X-rays of the 82 cases regarding them from different points of view

"Excellent Cases Among the 61 excellent cases the X-ray findings were equal on both sides in 48 cases

In 23 cases both knee joints were normal, i e the edges of the condyles were round (fig 2313), not sharpened

In 21 cases the condyles had sharp edges in both knees (figs 2313 a—d), seven of these cases had shown these changes before operation

In 4 cases lipping was found in both knees (fig 2313 e)

In seven cases the operated knee showed sharpened edges as shown in figures 2313 a—d, whereas the non operated knee was normal

capsule, limitation of motion, decalcification of bones and pain are not consequences of the bloody effusion, but are caused by *circulatory disturbances* due to unsuitable treatment (see Vol I/p 45) If a joint is overheated and subjected to unsuitable exercises, pain will follow and the whole limb will be held stiff The flow of blood to and from the site of injury will be slowed down because the *whole* leg is immobile and because the vascular nerves are irritated by pain Congestion of blood, i e, *passive hyperemia*, results This is followed by extravasation of fluid into the tissue with subsequent fibrosis If the whole injured limb is immobilized, passive hyperemia will disappear and ischemia will develop Muscular atrophy will result, whereas decalcification is mainly the result of passive hyperemia If, however, only the injured part of the limb is protected the rest of the body can be actively exercised This leads to *active hyperemia* Because of improved circulation effusions are quickly absorbed, no fluid will collect in the connective tissue, the muscles will not become atrophic since they work, and the bones will not lose their calcium since they have to bear weight

Let me repeat a sentence from Vol I/p 76

The essential problem of traumatology is the elimination of pain *in the injured parts by uninterrupted* immobilization *which, at the same time, permits normal use of all sound parts This treatment ensures active* circulation *in the injured tissues, which promotes rapid healing*

Method of Immobilization Stability is the most important result to be striven for after an injury or disease of the knee joint Ruptures of the collateral and cruciate ligaments must, therefore, be treated by uninterrupted immobilization until the ligaments have firmly united The better the achieved range of normal — not pathological — motion, the better off the patient will be A knee joint, which is not ankylosed, is only functionally stable, if it can be fully extended, i e, to 180° It is therefore not the range of mobility of the knee joint that is of paramount importance, but rather where this range lies A person who can move his knee from 180° to 150°, with a range of motion through only 30°, is much better off than another one who can move his knee from 160° to 70°, having three times the range of the former, for one can stand on a fully extended knee without any effort on the part of one's muscles But as soon as the knee lacks only 5° of extension, standing is possible only if the extensor of the knee, the quadriceps, is actively contracting How rotary movements connected with extending and flexing the knee are interfered with will be discussed later (see p 1624) A pen-knife illustrates these conditions If it is open, blade and haft will form an angle of 180° When dropped on a wooden floor it will stick there and remain open But if the blade is closed only by a few degrees and the knife is then dropped, it will snap shut

Overextension is even worse than loss of full extension, since it is only possible when the cruciate and collateral ligaments are overstretched (fig 2171) Every bandage or cast applied in overextension damages the knee joint and results in loss of its lateral stability

To ensure full extension at the end of treatment, the immobilizing plaster cast must be applied in full extension i e at 180° Ruptures of the collateral and cruciate ligaments are the only exceptions Immobilization in these cases

3 7 cases showed lipping as in figure 2313 e
4 9 cases had moderate arthrotic changes as in figure 2310
5 2 cases had advanced arthrotic changes as in figure 2311 b
6 1 case had severe arthrotic changes as in figure 2311 c

Arthrotic changes occurred in only twelve of the 82 cases These twelve patients had either pre operative or post-operative damage or were overweight, so that in a joint that was normal before operation no arthrotic changes appeared because of partial excision of the meniscus

None of the 82 patients sustained a *secondary tear* If they had been operated by another surgeon within these 18 to 25 years since the first operation, we would have discovered it at re examination

Disability Pensions Among the 57 patients insured against accidents only one patient draws a permanent pension, namely, the man with the fair result, who met with a new severe knee injury seven years after operation

The man with the below-knee amputation draws a pension due to the subsequent open fracture of the tibia and fibula The two patients with advanced arthrotic changes were not insured

General Survey of the Injuries of the Knee Joint

The man with an injured knee can only be spared serious damage by a careful clinical examination Economy should not be practiced with regard to X-rays, and local anesthesia must often be resorted to

For many years every knee injury was treated by massage and vigorous passive movements These measures are always harmful

The different types of knee injuries require entirely different treatment

Fractures of the femur and the tibia must be accurately reduced and immobilized until bony union has been achieved With appropriate exercise muscular atrophy and limitation of motion can be avoided

Injuries of the extensor mechanism (rupture of the rectus tendon, fracture of the patella with separation of the fragments, rupture of the patellar ligament and avulsion of the tibial tuberosity) can be treated only operatively by suture

Dislocations of the patella and the knee joint must be reduced as early as possible and immobilized for a long enough period Appropriate exercise of the leg and the whole body must be started at once

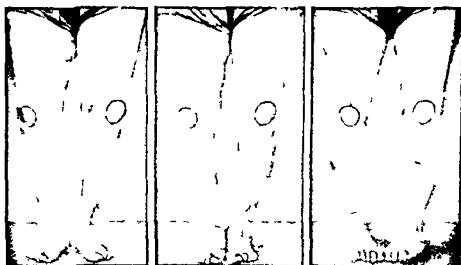
Fresh ruptures of the collateral and cruciate ligaments unite as a rule if they are immobilized for a long enough period (8—16 weeks), and if exercise of the leg and the whole body is carried out Suture is seldom indicated

In *tears of the meniscus* the only suitable treatment is operative removal of the torn portion and not extirpation of the entire meniscus

In *contusions* if a big effusion of blood is present the joint is aspirated and a pressure bandage applied An Unna s paste dressing and an elastic bandage will suffice as after-treatment

Treatment of Bloody Effusions Excessive importance used to be attached to bloody effusions and their sequelae If the joint is not irritated by application of heat and massage bloody effusions will disappear after a short while Such common disturbances as muscular atrophy thickening swelling of the

In the second stage there is a thickening corresponding to the course of the gracilis, sartorius and semitendinosus tendons extending obliquely upward and backward from the insertion of these tendons to lose itself on the medial aspect of the thigh There is marked tenderness over the area between the patellar ligament and the medial collateral ligament On X-ray in addition to the high position of the patella the abnormally pointed tubercula intercondyloidea can be seen and sometimes also the suggestion of lipping of the tibia and the femur



2314, March 19 1932

Shape of the legs in a 50 year old woman with typical painful knee Slight varus position at the knee with internal rotation of the lower portions of the tibiae
Left With feet turned slightly out the patellae point markedly outward
Middle With feet parallel the patellae still point outward
Right With feet turned markedly in the patellae point anteriorly due to the internal rotation of the lower portions of the tibiae

In the third stage the whole of the knee joint is more or less thickened This is not caused by effusion, but by thickening of the capsule and soft parts The swelling on the medial side over the tendons is well marked The knee cannot be fully extended either actively or passively There is a flexion contracture of 5° to 10° The tenderness on the inner side of the joint is always well marked and may also be present on the outer side and around the edge of the patella, in the region of the plicae alares and the thickened tendons With the knee extended (170°) and the quadriceps relaxed lateral mobility of the patella is much restricted X-rays show marked lipping at the edges of the tibia, femur, and patella, and the spines of the tibia form oblique points that tend to meet It is striking that the patella appears to be 2 to 4 cm above the joint space on X-ray At first often only one side is affected, later both sides, but one is usually worse than the other

Climbing stairs, particularly going downstairs, is only possible in this fashion the patient no longer takes each step to the next stair below, but the trailing leg is placed at the side of the leading one The involved leg is always the leading leg The lower leg is often slightly swollen and the muscles of the knee are weaker than usual

should be carried out at a flexion angle of 170°, so that the ruptured ligament shrinks slightly and does not become too long

84 THE TREATMENT OF THE COMMON FLEXION CONTRACTURE OF THE KNEE

Contracture of the knee in a more or less flexed position is common after all injuries and diseases of the leg As the slightest limitation of extension of the knee causes great disability, every care should be taken to prevent it or if it is already present to overcome it All patients with leg injuries who are able to walk should be entirely undressed during ward rounds It is only in this way that faulty gait can be recognized and corrected Slight degrees of contracture are easily overlooked in half clothed patients

Treatment For the treatment of flexion contracture of the knee an application of Unna s paste is made as described on page 1514 Between the first and second layer longitudinal strips of gauze are applied to which an iron stirrup (Vol I/fig 147) is attached A traction weight of 1 to 3 kg is led over a pulley (Vol II/fig 1576), the lower end of the bed being raised 30 cm A wooden footrest is placed in the bed for the sound foot *This traction should cause no pain* To avoid pain a small pad is initially placed under the knee A plaster cast is applied over the lower leg so that the Unna s paste does not slip A 60 cm long plaster splint is made from a plaster roll and cut into two One half is placed on the inner and the other one on the outer side of the lower leg from the ankle to the knee and a circular roll is applied over these The patient is allowed to walk about during the day, but during the night the traction weight is applied Exercises for the knee are done with the help of the knee support (Vol II/figs 1574, 1575) General exercises are also carried out

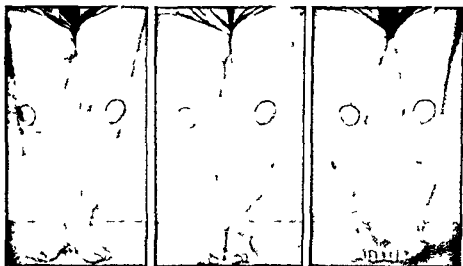
85 PAINFUL KNEES IN HEAVY WOMEN

One of the commonest clinical pictures is that of the woman over forty who complains of pain in the knee It always affects a certain type of woman These women are rarely over average height, but are inclined to corpulence The normal valgus position at the knee is diminished or there is even a suggestion of varus The angle of torsion of the tibia is increased so that the transverse axes of the ankle and the foot face inwards if the patella faces forwards But these patients usually stand so that the transverse axis of the ankle lies in the frontal plane and the patellae face outward The patellae are usually strikingly high (fig 2314)

When this type of woman has reached a certain age, usually about 40, pain occurs on the inner side of the knee joint At first it only follows prolonged standing and walking It gradually appears earlier until finally there is pain at every step It is particularly severe on going *downhill* In late cases it no longer subsides with rest or at night

In the early stages the knee presents nothing especially abnormal beyond what has been described above Pressure on the front of the joint space is painful No changes are seen in the X-ray except the high position of the patella There is not much difficulty in going downhill

In the second stage there is a thickening corresponding to the course of the gracilis, sartorius and semitendinosus tendons extending obliquely upward and backward *from the insertion of these tendons to lose itself on the medial* aspect of the thigh There is marked tenderness over the area between the patellar ligament and the medial collateral ligament On X-ray in addition to the high position of the patella the abnormally pointed tubercula intercondyloidea can be seen and sometimes also the suggestion of lipping of the tibia and the femur



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Such women usually have flat feet The front part of the foot is markedly bent into supination and is very unstable

Usually the hip joints show no changes and the other joints of the body are normal

This disease is very uncommon in men

The complaint usually has a gradual onset without any apparent external cause *It has nothing to do with rheumatism* and salicylates have no effect upon it Many consider that it arises from the disturbance of *internal secretion,* and is particularly related to changes in the ovaries and the onset of the menopause I regard it as of a *mechanical nature* as it only occurs in women of a certain constitution and a certain shape of bones and joints All show diminished valgus of the knee and an increased inward rotation of the tibia The complaint occurs first about 40, because at this time adiposity increases on account of ovarian changes Pain is brought about not directly but indirectly by disturbances of internal secretion In general, gait and all movements depend upon the function of the genital organs The elasticity of the gait becomes less if these are removed

Whether the pain in the knee is regarded as the result of a change in internal secretions or not, the initiating cause always lies in disturbed mechanics As adiposity and body weight increase at 40, the muscles become weaker and these weakened muscles must support an increased weight The result is flattening of the arch of the foot, an increased inward rotation of the leg and increased difficulty in bearing weight These women walk less, on account of pain which increases the obesity and the difficulty of bearing weight Truly a vicious circle

Movement of the Joints of Women with Typical Painful Knees

The mechanism of flattening of the foot first became clear when it was related to the increase of normal rotation and torsion Movements of rotation can only be visualized in three dimensions, most people however only think in two dimensions, and the majority of errors of position, errors in standing, and errors in shape are considered in one plane only and therefore are not understood in regard to the significance of their origin

The usual X-ray picture which presents the bones on a flat surface, has further contributed to thinking in two rather than in three dimensions

When the muscles have become weakened with the increase of body weight and the foot must carry heavier load, loosening of the ligaments of the foot takes place the fore foot rotates into supination and abduction, the heel into pronation, the head of the talus sinks down and twists inwards As the talus is fixed in the ankle mortise this inward rotation also turns the tibia If the knee is extended, the inward rotation takes place at the hip joint and if the knee is flexed, it takes place at the knee joint At every step, and with every burden this morbid internal rotation of the leg follows the dropping of the arch of the foot In women who have already a decreased valgus position of the knee as well as an increased inward rotation of the tibia, the inward rotators will after years or decades become shortened and there will be an inward rotation contracture at the hip and especially at the knee Following

the shortening of the internal rotators, complete outward rotation of the tibia on the femur which is necessary for complete extension from 175 to 180° is no longer possible There results a slight flexion contraction of the knee As a result of this flexion contracture (which is actually a contracture of inward rotation in respect to its development) and the joint surfaces are no longer congruent, the medial meniscus is overloaded As the abnormal strain continues the entire joint is affected, first the lateral meniscus, then the cruciate ligaments, the plicae alares, and finally the whole capsule of the joint is irritated Usually the insertion of the muscles into the medial tibial condyle is very tender, sleep being often disturbed by this Wherever new surfaces of bone are exposed to strain typical lipping occurs, and the attachments of the cruciate ligaments are stretched

In going *downwards* on a so severely deranged and weakened leg, the knee of which is already involved in a slight flexion contracture of 5° to 10°, supination of the fore-foot and inward rotation of the talus and tibia occurs when weight is put on the leg When the leg is straight the hip is rotated inwards Flexion of the knee which follows is not accompanied by outward rotation of the femur because, the knee is already slightly flexed, the subsequent inward rotation of the femur cannot take place to the normal extent The weakened vastus medialis is no longer able to give sufficient restistance in the presence of this inward rotation The knee is therefore no longer fully capable of bearing weight, consequently when the patient goes downstairs she can only do so by putting both feet on each step and by holding on to the wall or the rail Pain is further aggravated by the degenerative changes of the meniscus that are produced by the mechanical derangement of the knee

Treatment of Painful Knees in Heavy Women

As the manifestations described above are mechanical in origin, treatment should aim at correcting the faulty mechanics The best and simplest method is the application of a light supporting bandage, an Unna's paste boot If this is applied as described on page 1514 the foot will be held in pronation and the heel in supination The arch of the foot will be restored and the dropped head of the talus will be raised and rotated outwards Most patients ask why the foot and lower leg are being bandaged when the pain is in the knee The immediate result is often very gratifying Sometimes she can at once go downstairs in the usual way, although for weeks and months she had been able to make her way only by putting both feet on each step Often the pain is already so far ameliorated the first night that she can sleep undisturbed During the daytime the knee is supported by an elastic bandage, which is taken off at night The constipation which usually accompanies this condition is best treated with Epsom salts A daily evacuation should be insisted upon

If the bandage becomes loose after a few days due to decrease of the swelling of the foot and leg, a new one is applied The patient lies down for half an hour with the lower leg raised and the knee flexed to reduce the swelling further

Usually not only does the pain disappear but also the swelling and flexion contracture, which is really a contracture of inward rotation This occurs in

the course of one to three weeks, and then the patient can once more go downstairs normally

A properly shaped arch support is then prescribed The Unna's paste bandage is kept on from one to three months — or longer if necessary, according to the severity of the disease

The relief may last for ten years or permanently

I have treated over 3000 cases of this kind since 1919 Many of these for months and years had had various other types of anti rheumatic treatment, hormones, physiotherapy and baths without results I have tried to treat these women with diathermy, but unless the Unna's paste was applied at the same time, improvement was insignificant Prepared Unna's paste bandages and other adhesive bandages have never given such good results as the Unna's paste method described.

Since in this type of knee pain the medial meniscus is tender to pressure it has sometimes been surgically removed in the treatment of this condition When it is removed it is found to be much altered The symptoms, however, do not improve but become worse Whoever does such an operation on these women has no proper comprehension of the nature of the disturbance

86 OPEN INJURIES OF THE KNEE JOINT

The open injuries of the knee joint belong to the most dangerous injuries, since they may be complicated by infection followed by limited motion, contractures ankylosis loss of the limb, or even death

It used to be considered that when infection occurred the knee joint became stiff in about one third of the cases, amputation became necessary in another third owing to sepsis, and one third ended fatally

The treatment after infection of a knee joint usually lasts months

Treatment of Open Injuries of the Knee Joint

All severe complications of wound infection can be avoided, if one keeps in mind that every open wound in the knee region may have penetrated this largest joint of the body if the open wound is thoroughly debrided in its full extent with the scalpel within the first 6 to 8 hours, if the skin is sutured after inclusion of a drain and if uninterrupted immobilization follows until the wounds of the soft tissues and bones have healed The simultaneous use of antibiotics makes the results safer still

Debridement of the wound with the knife is carried out under local anesthesia according to the rules given in Vol I/pp 139—174

In *stab wounds* e g by a rusty nail the whole wound canal should be laid open by a longitudinal incision widely enough for adequate survey and excised

In rural districts injuries caused by a *blow with an axe* are quite frequent among lumbermen and carpenters Such a wound is extended proximally and distally and the surfaces are excised If the cut has penetrated cartilage or bone 1 to 2 mm each are removed from the two wound surfaces by means of a chisel

When a person falls, becomes wedged against or is dragged along the road, extensive skin avulsions will often occur in addition to the wounds In such cases the skin must be split lengthwise to the remotest corner in order to clearly see all foreign bodies as well as all torn and soiled tissue, which will then be removed We have observed that sometimes the muscles are torn for as much as 20 cm underneath the skin and are soiled by mud If only the edges of the wound are excised and the skin is sutured, without the lacerated and soiled tissue having previously been removed layer by layer down into the depth, the most severe forms of wound infection will result

If, besides wide laceration of the knee joint, the *bones* are *fractured*, as in Vol II/figs 2061—2068, the femur, or in figures 2262 a—d, femur and patella, or in figures 2210—2212 the patella, or in figures 2253—2262 the tibial head, not only are the lacerated soft-tissue wounds accurately excised, but the dirty parts of the bones are also chiseled off or removed with a rongeur This is comparatively easy, as the dirt never penetrates the cortical bone for more than 0 5 to 1 mm, nor the cancellous bone for more than 5 to 10 mm These conditions must be emphasized, as again and again one reads that wound excision should not include the bones Cleaning of the bones, however, is as a rule easier to perform than cleaning of the soft tissue

Hemostasis All bleeding vessels are clamped immediately but, for the reasons stated in Vol I/p 153, not ligated

Cleaning of the Joint Cavity and Use of Antibiotics Some take the view that the whole joint cavity forms part of the wounded region, and that consequently debridement should include removal of the entire capsule with all its pouches This cannot be done without destruction of the knee joint, nor is it necessary to do so, as is proved by our results (see p 1630) We have heard of one case where, after a simple cut with an axe, actually the whole joint was exposed for total excision of the joint capsule The result was a severe infection When the contused and soiled tissue has been excised, we often wipe out the wide open joint cavity with a dry or moist sponge, thus removing grains of sand, particles of road dirt, and other foreign bodies Pathogenic organisms will certainly remain in the joint, but the synovial membrane will destroy them as successfully as does the peritoneum, if the circulation is good Instillation of the old fashioned chemical agents and suture of the capsule will always lead to irritation and serous effusions Tension in the tissue and consequent impairment of circulation results thus increasing the danger of infection Severe late complications are caused by irrigation with carbolic acid If such joints are examined after some years, they usually show severe damage to the cartilage and marginal exostoses, although the patients report that they had no complaints within the first few years after the injury Accurate wound excision is followed by local and general application of penicillin and, if necessary, also of other antibiotics

Drainage of the Wound In every laceration of the knee joint we insert a drain, on principle It is however, not inserted through the wound, but through a new incision made in healthy skin and at the most dependent point The drain should be stitched to the skin so that it will not slip into the joint

In big wounds we sometimes insert two or three drains Drainage of the fluids prevents tension in the damaged soft-tissue Lest these drains be forgotten, especially during busy times, the fact that a drain is in the wound is written down in clearly visible letters on the dressing and noted on the patient's chart

Suture of the Wound Contrary to most other surgeons we leave the wound of the joint-capsule open on principle, so that no foreign bodies are buried The skin and nothing but the skin is closed Nor are the other layers of the tissue sutured In the literature on this subject the fear has repeatedly been expressed that this method may permit synovial fluid to ooze into the wound, thus causing extensive collections of fluid However, we can dispel these doubts completely Suture of the capsule is usually followed by big synovial effusions which sometimes lead to painful and dangerous tension If, however, *the capsule is left open, the synovial fluid can flow into the tissue outside the* joint cavity and will be at once absorbed We have therefore never seen any accumulation of fluid if the joint capsule has been left open

Application of a Pressure Bandage After suture of the skin the wounds are covered with sterile gauze Over it a layer of sterile cellulose cotton is placed around the knee and this is bandaged with slight pressure to prevent secondary hemorrhage The edge of the bandage must not reach the skin

Repair of Skin Defects If part of the skin has been lost through trauma, one must try to cover the defect by a sliding skin flap so as to be able to close the joint Big longitudinal incisions are made at one or both sides of the wound at a distance of 7—8 cm from the wound margin The skin is moved together with the subcutaneous tissue and the wound is closed The flaps must not be too narrow and must not be detached from the underlying surface because of the danger of necrosis

Repair of Skin Defects Caused by Sliding Flaps After application of an immobilizing plaster cast, and after this is windowed, the new defects are covered by dermatome flaps or Reverdin s pinch grafts (Vol I/figs 157—158 c)

Immobilization In soft tissue wounds a plaster cylinder is applied from the hip to the ankle as in figures 2175—2177 Certain professions or occupations, e g , taxidermists butchers etc , present unusually high risks of infection In such cases a plaster hip spica should be applied

Windows are cut over the sites of the wound and the drain

Placing the Leg After application of the plaster cast the leg is placed on an oblique splint to provide for good circulation of blood A hot water bottle is placed below the leg (see Vol I/fig 157)

Removal of the Drains It is essential that the drains be removed within 24 hours or 36 hours at the latest By no means should they be left longer Many warn against the insertion of drains into a joint or its vicinity saying that it leads to infection and subsequent ankylosis This can in fact occur if the drains are left in place for too long a time After removal of the drain the wound is not left without a dressing but covered with a sterile sponge sprinkled with a few drops of Peruvian balsam

Treatment of Wounds Without Dressings After 12 to 24 hours the pressure bandage is removed The wound is subsequently treated open, that is without

any dressing Only the site of the drains is covered with a sponge The exposed treatment of wounds is especially important in skin abrasions and avulsion of the skin since the skin may become moist if it remains covered, and inflammation may penetrate into the deeper layers

Removal of the Stitches As no sutures are buried in the deep layers, the skin stitches must remain for two to four weeks

Duration of Immobilization In simple soft-tissue wounds without damage to the skin the plaster cylinder is removed after 14 days

In severe contusions and necrosis of the skin the plaster cylinder is retained until the dry skin has come off by itself It should not be cut away too soon as this might open the joint New skin sometimes takes as long as six to eight weeks to form in this area

In the presence of concomitant fractures of bones the duration of immobilization depends on their consolidation

Exercises Toes and ankle joints are actively moved through their full range of motion from the first day on The muscles of the thigh are strongly contracted from the third week on

Further Treatment After removal of the immobilizing plaster cast an Unna s paste dressing is applied from the web of the toes to the knees, and an elastic bandage is worn around the knee during the dav Then exercises over the knee support (figs 1574, 1575) are carried out *These exercises must not cause pain* or they will lead to effusions, thickening and subsequent limitation of motion (see Vol I/p 45)

In simple soft-tissue wounds, which are healed within two weeks, motion will be complete after a few days In the other cases it will take longer, if the wound was bigger and a longer period of immobilization was necessary

Dangers of Suture of the Wound Without Painstaking Debridement

Again and again stab wounds of the knee joint and wounds of the knee caused by an axe are treated by closure of the comparatively small and seemingly simple wounds *without previous debridement* with the scalpel Completely ignoring the grave dangers, the patient is given no immobilizing cast and many a patient is even sent home walking If elevated temperature and pain in the joint occur on the following day, salicylates are frequently ordered (and nowadays antibiotics) When the symptoms increase and become severe the patient is after some days sent to a hospital Empyema of the knee joint or even a capsular phlegmon or septicemia will be found If only empyema of the joint is present, this may be healed completely in some cases by local and general application of antibiotics In former times, after hospitalization through 6 to 12 months ankylosis resulted in some cases Many patients lost limb or life If the fresh wound is not sutured but left open, it will sometimes heal even without debridement, though the result is very uncertain

Treatment of Infected Open Injuries of the Knee Joint

These injuries are treated in the same way as infected gunshot wounds of the knee joint (see p 1635)

End-results of Open Injuries of the Knee Joint

In the 13 years from 1926 to 1938 we treated 78 open injuries of the knee joint The were reviewed by Kromer He classified them according to *cause and according to type of injury into the following eight groups*

Group	Cause and Type of Injury of Open Wounds of the Knee Joint	Number of Cases	Duration of Treatment in Days		
			Hospital	Out Patient Dept	Total
I	Stabs and cuts without major soft tissue injuries	12	21	28	49
II	Stabs cuts circular saw etc with major injuries of the soft tissues (muscles tendons ligaments) and the bones	11	24	37	61
III	Contused lacerated wounds (auto mobile accidents etc) with or without major injuries of the muscles tendons ligaments bones menisci or open dislocations of *the knee joint*	17	50	37	87
IV	Wounds caused by shooting ex plosion or foreign bodies	7	13	22	35
V	Open fractures of the patella not necessitating secondary suture of the patella	6	29	68	97
VI	Open fractures of the patella necessitating secondary suture of the patella	2	104	76	180
VII	Open fractures of the femoral or tibial condyles	10	77	130	207
VIII	Open wounds of the knee joint from different causes with con comitant injuries of greater im portance and severity	13	73	88	161

Of these 78 cases 76 were at once excised and immobilized after insertion of a drain and suture of the skin whereas the remaining two cases were not In one of these two cases the perforation of the knee joint was not recognized Empyema of the joint and ankylosis resulted The other patient had sustained such severe concomitant injuries in other parts of the body that early death was expected, and excision of the big laceration of the knee was not undertaken Surprisingly the patient recovered but died from severe infection of the knee joint a few days later Thus, both non excised cases resulted in severe infection of the knee joint

Of the 76 cases treated by excision of the wound, 74 healed without complication Infection occured in only 2 cases, one developed a lowgrade infection without severe suppuration or fever, and one an empyema of the joint Both healed with the knee ankylosed in extension Of the 74 patients who recovered without infection of the joint, four died, viz one from pulmonary embolism, one from pneumonia and two due to other severe injuries

87 GUNSHOT WOUNDS OF THE KNEE JOINT

Frequency Among the gunshot wounds of joints those of the knee joint are the most common They amount to about one third Jimeno Vidal has observed 433 (32 2%), Bohler 64 (36 4%), Exner with Vollbrecht and Wieting 132 (42 4%)

Classification Jimeno Vidal [1] observed amongst his 433 cases

(1) 77 (17 7%) pure gunshot wounds of the soft-tissue,

(2) 83 (19 2%) gunshot wounds of the knee joint with slight injury of the bone by perforations, creases, or small fissures of the bone,

(3) 10 (2 4%) comminuted fractures of the fibular head, all combined with paralysis of the peroneal nerve

(4) 63 (14 5%) comminuted fractures at the upper end of the tibia,

(5) 63 (14 5%) gunshot fractures of the patella, 46 without displacement and 17 with displacement of the fragments,

(6) 89 (20 6%) gunshot fractures at the lower end of the femur, 18 of which were supracondylar or diacondylar fractures 16 intraarticular supracondylar fractures, 22 gunshot fractures of the medial condyle, and 33 gunshot fractures of the lateral condyle,

(7) 48 (11 1%) comminuted fractures of both articulating bones

Nerve Injuries Of the 433 cases 17 (3 9%) had nerve injuries 10 of these cases belonged to the group of comminuted fractures of the fibular head

Vascular Injuries Among the 433 cases the popliteal artery was lacerated seven times (1 6%) Gangrene of the leg resulted in all these cases

TREATMENT OF GUNSHOT WOUNDS OF THE KNEE JOINT

Treatment in the First Aid Station and at the Clearing Station

The treatment of shock, arrest of hemorrhage, dressing of the wound, relief of pain, keeping the patient warm, protection against tetanus, and the application of penicillin are carried out as in the treatment of gunshot wounds of the hip joint (see Vol II/pp 1143, 1144)

Bandages for Transport to the Main Clearing Station or Evacuation Hospital Immobilization is easy in gunshot wounds of the soft parts in perforations or grooves of the bones, and in gunshot fractures of the patella A splint extending from the ankle to the hip will suffice Even the sheet iron boot will serve the purpose It will also be sufficient in minimal fractures of the tibial head or one femoral condyle In a complete fracture of the femur the hip must be included in the bandage This is carried out in the same way as for gunshot wounds of the hip joint (see Vol II/pp 1143, 1144)

[1] Jimeno Vidal Arch orth u Unfall chir *41* 649—684 1941

Questions We Should Ask Ourselves to Avoid Failures When Treating Gunshot Wounds of the Knee Joint in the First Aid Station and at the Clearing Station

They are the same as in gunshot wounds of the hip joint (see Vol II/p 1145)

Treatment in the Main Clearing Station or Evacuation Hospital

Treatment of Shock Many patients with gunshot wounds of the knee joint have lost a large amount of blood and are in shock They should be wrapped in warm blankets and given hot drinks and anodynes Some patients may require plasma or blood For dressing, cleaning of the wounds and splinting only a minimum of clothes should be removed In Vol I/p 136 is described how it should not be done

Recognition of Gunshot Wounds of the Knee Joint This is usually easy if, in all injuries of the region of the knee, one keeps in mind that the injury is likely to have penetrated the joint In some cases synovial fluid flows out of the wound This confirms the diagnosis

Physical Examination As soon as the patient has recovered from shock one examines the motion of the joints, sensibility and pulsation on the dorsum of the foot and behind the medial malleolus to see whether nerves and vessels are intact and whether the leg can be saved or must be amputated at once

Avoidance of Wound Infection Wound infection is best avoided by accurate excision of the wound followed by uninterrupted immobilization in a plaster hip spica Antibiotics are also given

Cleaning the Wound with the Scalpel This is carried out as in gunshot fractures of the femur (see Vol II/p 1483)

Removal of the Patella In comminution of the patella it is best removed altogether If removal of the patella is not necessary, the fragments should not be sutured after excision of the wound, but only after the wound has healed, i e, 6 to 8 weeks later

Removal of Bone Splinters Contrary to the practice in fractures of the shafts, loose bone splinters should as a rule be removed

Primary Resection of the Joint In complete comminution of one or both joints ends primary resection of the joint may be performed in the presence of very extensive wounds with severe danger of infection In simple through and-through gunshot wounds and with good condition of skin the bones should be preserved Severe shortening due to extensive resection can be treated later on by shortening the sound femur as shown in M N [1]/figs 705 to 734

Since the bones often become severely displaced after resection, it is ex pedient to drive in two Steinmann pins obliquely from the front of the tibial head so that they cross This will serve to fix the bones until the application of the immobilizing plaster hip spica (see p 1685 and fig 2370 b)

Treatment of Nerve Injuries Nerve suture should be attempted if the sciatic nerve or one of its two branches has been severed

1 Medullary Nailing of Kuntscher by Lorenz Bohler translated by Hans Tretter Baltimore Williams & Wilkins 1948

Treatment of Vascular Injuries Severance of the popliteal artery usually leads to gangrene We therefore used to carry out an immediate primary amputation Suture of the vessel is rarely possible In the Korean War American surgeons successfully implanted preserved vessels to bridge defects of large arteries

Skin Suture in Gunshot Wounds of the Knee Joint Whereas suture of the skin should strictly be omitted in all war injuries with the exception of the widely open pneumothorax and some gunshot wounds of the brain, it should be performed in some gunshot wounds of the knee joint, namely in those with slight damage of the soft parts within the first six to eight hours or even later As all extensive wounds of the knee region usually become infected if left open, the risk of wound suture should be taken, since this may help and, with timely removal of the stitches, will never do harm This concerns pure gunshot wounds of the soft parts and gunshot fractures such as grooves and perforations, fissures, wounds after removal of the lodged bullet, gunshot fractures through the patella, the fibular head or one condyle, if thorough cleaning of all the soft parts with the scalpel (and of the bones with the chisel) has been possible Antibiotics should be administered locally and generally In comminuted gunshot fractures of the joint suture of the wound is rarely possible

Drainage of the Wound Insertion of a drain is essential before suture of the skin We should like particularly to emphasize this, because one often reads the contrary The drain, however, must be removed within the following 24 to 36 hours The reason is given in the chapter on open injuries of the knee joint (p 1628)

Amputation In complete comminution of both joint ends and rupture of the popliteal artery, amputation should as a rule be performed at once since this injury will always lead to gangrene and sometimes to fatal secondary hemorrhage The amputation stump should never be closed by primary suture If the wound is clean and the patient develops no fever, secondary suture should be performed five or six days later (see Vol I/p 185)

As early as 1878 Bergmann emphasized the importance of immobilization in gunshot fractures of the knee joint At Plewna he succeeded in healing gunshot fractures of the knee joint, which were then regarded as almost invariably fatal, by omitting probing and digital palpation, and by the use of immobilizing plaster casts

Dressing for Transport to the Special Hospital The best transportation bandage is the plaster cast As an exception the plaster cylinder will suffice in gunshot wounds of the soft parts and in gunshot fractures through the patella or the fibular head In gunshot fractures of the tibial head and the femur a plaster hip spica should be applied as in gunshot fractures of the femur (see Vol II/p 1486) If there is no possibility of applying a plaster cast, splints should be used (see Vol II/p 1487)

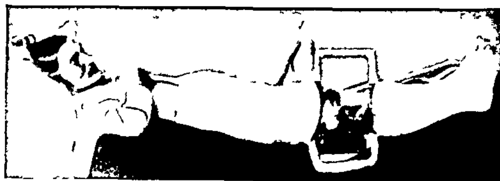
For *fenestration marking of the transportation cast* and *time of transportation* the same rules apply as in gunshot wounds of the hip joint (see Vol II/p 1208)

Questions We Should Ask Ourselves in Order to Avoid Failures When Treating Gunshot Wounds of the Knee Joint in the Main Clearing Station or Evacuation Hospital

The questions to be asked in gunshot wounds of the hip joint (see Vol II/p 1148) and in gunshot fractures of the femur (see Vol II/p 1489) also apply in the case of gunshot wounds of the knee joint

DEFINITIVE TREATMENT OF GUNSHOT WOUNDS OF THE KNEE JOINT IN THE SPECIAL HOSPITAL

The *treatment of shock* and the *maintenance of the immobilizing transportation cast* are carried out as in gunshot wounds of the hip joint (see Vol II/p 1149)



2314 a August 15 1916 at Bozen

Plaster hip spica with bridged window in a severely infected gunshot wound of the knee joint It extends from the costal margin to the toes The knee region is exposed and the opening bridged by four iron bars The patient had been without immobilization and had run high temperatures for two months After application of the plaster cast the temperature dropped to normal within two weeks and the patient improved quickly As that was my first fenestrated and bridged plaster hip spica the flexor side of the toes was left free and the knee overextended instead of being flexed 10°

Treatment of Aseptic Gunshot Wounds of the Knee Joint

In *simple through-and-through gunshot wounds of the soft parts* the immobilizing transportation bandage may be left if it fits well

Gunshot fractures of the patella grooved and perforating gunshot fractures of the tibia or the femur are treated in the same way as simple gunshot wounds of the soft parts

Gunshot fractures of the femur or of the lower leg with displacement are treated like extra-articular gunshot fractures, i e as a rule by traction if no fever develops within one week

Lodging wounds of the knee joint are also treated in a plaster cylinder or on a Braun splint The projectiles should be left in if they are small and unlikely to disturb motion in future Bigger bullets and shell fragments should be removed not before two months if the point of entry was clean and punctured In granulating wounds we used to operate as late as two months after closure of the wound to avoid severe infection Under the protection of antibiotics such operations can now be performed before closure of the wound

Treatment of Infected Gunshot Wounds of the Knee Joint

Of my 64 gunshot wounds of the knee joint 48 (75%) were infected, of Jimeno Vidal's 433, infection occurred in 247 (57%) Among these were 85 (19 6%) cases of *synovitis serosa haemorrhagica*, 51 (11 8%) cases of empyema of the joint, 99 (22 8%) cases of capsular phlegmon, and 12 (2 8%) cases of putrid infection

Infection of the knee joint is extraordinarily dangerous Formerly up to 30% of the patients with infection of the knee joint died The survivors often lost their leg, or developed a flail joint, subluxation, flexion contracture, bony ankylosis, or limitation of motion Flail joints, subluxation and flexion contracture can, as a rule, be avoided

Most important in the treatment of every infected gunshot fracture of the knee joint is the *provision for good drainage of pus and at the same time uninterrupted immobilization* in a plaster hip spica and regular administration of antibiotics Exercise of all non-immobilized joints is necessary

The *synovitis serosa haemorrhagica* usually heals with complete uninterrupted immobilization especially if antibiotics are given locally and generally at the same time If immobilization is omitted, empyema of the joint and in some cases capsular phlegmon will, as a rule, develop

Aspiration of Pus in Empyema of the Joint Either the whole joint or the anterior compartment alone is firmly distended with pus Under local anesthesia a large bore needle is inserted near the cranio-lateral edge of the patella and the pus withdrawn Local and general use of antibiotics has proved especially successful

Drainage of Pus by Joint Incision If the fever does not subside in spite of several aspirations, and the joint again and again fills with pus, drainage must be provided for by adequate incisions On both sides of the patella an incision is made and a short drainage tube is inserted in each If the temperature does not subside and the popliteal region is tender on pressure, the posterior compartments should be opened under general anesthesia and in a bloodless field This has become a rare necessity since the use of antibiotics began

According to Wustmann[1] it is done in the following way the posterior pouches of the joint are incised by cross incisions placed under the semitendinosus and under the biceps muscles The posterior portions of the femoral condyles are partly excised (after Lawen) either in the coronal plane or in a curve The flaps of the capsule resulting from the cross incisions are stitched to the skin as in a marsupialization operation Two drains are inserted in each of the openings, into the intercondylar fossa, or towards the upper pouches of the joint capsule and are fixed with sutures This promotes good drainage in empyema, and lavage of the whole joint cavity is possible The dangerous para-articular phlegmon at the upper part of the popliteal region can thus be avoided

Drainage of Pus in Abscesses of Capsular Phlegmon If an empyema is not evacuated in time, the pus will burst through the capsule, usually at first through the upper end of the suprapatellar pouch The suppuration spreads

[1] Wustmann Die Behandlung infizierter Knieverletzungen Zentralbl f Chir 72 1186—1190 1948

quickly along the femur and reaches the hip If the pus bursts dorsally towards the calf, a sudden swelling of the lower leg is observed Usually the whole joint area is severely swollen and thickened without evidence of fluid in the joint Pain is usually severe There is tenderness in the popliteal space The temperature is high and usually spiking (septic) Under these circumstances the abscesses must be widely exposed under general anesthesia in a bloodless field All pouches must be digitally explored to avoid retention of any pus In the thigh the incisions are placed mainly on the lateral side, sometimes also in the region of the adductors (Vol I/figs 244—246) In the lower leg the abscesses lie in front of the gastrocnemius They must be opened from the sides and not posteriorly through the calf

Immobilization After opening of the abscesses spreading of infection should be halted by complete uninterrupted immobilization and the use of antibiotics Proper immobilization is only obtained in a plaster hip spica extending from the tips of the toes to the costal margin The plaster hip spica is applied as shown in Vol II/figs 1627—1640 A plaster cylinder is entirely inadequate For application of the plaster hip spica a screw traction apparatus as in Vol II/figs 1577 and 1626 or some other extension appliance is used, or the patient is placed on a pelvic rest and two small tables as in figures 1627—1640 The plaster cast is fenestrated over the sites of the wounds, in big wounds it may be bridged by iron bars (fig 2314 a) When all abscesses have been completely opened, the closed plaster cast has proved the best treatment In spite of wide opening of the abscess cavities and in spite of good immobilization, patients with capsular phlegmons sometimes run high temperatures for several more weeks

Further Treatment of Gunshot Wounds of the Knee Joint

X-rays In fractures with displacement anteroposterior and lateral X-rays are taken every 2—4 weeks *Treatment of the wounds, treatment without dressing care of the plaster cast avoidance and treatment of the window edema are* carried out as in gunshot fractures of the femur (see Vol II/pp 1492—1496) The best immobilization is obtained by the closed plaster hip spica

Wide Exposure of the Joint and Immobilization with the Knee Flexed at a Right or at an Acute Angle If the temperature does not subside in spite of opening of the abscesses and in spite of good immobilization, and if the general condition becomes worse, some surgeons widely expose the joint and apply a plaster cast in marked flexion We have seen a number of such cases The end-results were as a rule poor We therefore advise against this method

Secondary resection of the joint used to result in high mortality In our opinion amputation should be performed in those severe cases in which the general condition deteriorates quickly in spite of wide exposure of all abscesses, in spite of complete uninterrupted immobilization and in spite of the administration of antibiotics Such cases have however, become rare with regular use of antibiotics

Amputation In infected comminuted fractures and in spreading capsular phlegmons amputation should not be delayed too long as these septic patients may then die in spite of the amputation In putrid infection and in septic

secondary hemorrhage from the popliteal artery, amputation should be performed promptly as these patients otherwise die The amputation stump should never be closed by primary suture, 5 or 6 days later secondary suture of the skin may be performed if the wounds are clean and the temperature is normal (see Vol I/p 185)

Avoidance of Flail Joints Flail joints can be avoided if the resected bone stumps are first fixed with two pins and then immobilized in a plaster hip spica uninterruptedly until bony union has been achieved Greifensteiner s compression method has given the best results (figs 2369—2370 d)

Avoidance of Subluxation Subluxation can also be avoided by complete, uninterrupted immobilization

Avoidance of Flexion Contracture Flexion contractures are avoided by application of traction or plaster casts until all signs of inflammation have disappeared

Repair of skin defects and *sequestrectomy* are performed in the same way as in gunshot fractures of the femur (see Vol II/p 1500)

Exercises are carried out as in gunshot fractures of the hip joint (see Vol II/pp 1157, 1158)

Duration of Immobilization Aseptic gunshot wounds of the soft parts are immobilized in the plaster cylinder on an oblique splint In grooves and perforations of the bone and in fractures of the patella without displacement 5 to 6 weeks will be necessary Fractures of the femur or tibia are immobilized until bony union has been obtained, i e, 8 to 10 weeks

In empyema of the joint the immobilizing cast is usually retained for six more weeks, after the patient's temperature has returned to normal

In capsular phlegmon the plaster hip spica will not be removed until 6 to 8 weeks after the temperature has become normal A plaster cylinder is then applied as in Vol II/figs 2175—2177, until bony ankylosis has been achieved

After-treatment After removal of the plaster cast an Unna s paste dressing is applied from the web of the toes to the knee, and an elastic bandage wound round the knee Unless there is bony ankylosis, exercises are carried out over the knee-support (Vol II/figs 1574, 1575) As soon as the knee can be flexed to 120° exercises are begun on the mountain climbing apparatus (Vol I/figs 21, 22) Thus, motion of the ankle, knee and hip joints is improved as well as the power of the muscles The latter are best strengthened by normal use, i e, walking Warm baths and swimming follow later As soon as walking no longer causes pain, light work and sports are begun

Energetic massage and forceful passive motion must be omitted, since they might cause severe infection even after months We have known a number of patients who thereby sustained severe capsular phlegmons or lost their leg (cf the patients in Vol I/p 73)

Exercise must not cause pain (see Vol I/p 45)

Treatment of Ankyloses of the Knee Cases of bony ankylosis may be treated by arthroplasty, as an exception Those who do physical work usually walk better with a knee ankylosed in a suitable position than with a mobilized knee that often lacks stability We therefore warn most patients against an

arthroplasty of the knee In isolated ankylosis of the patella, the latter is completely removed or is mobilized and covered with fascia

Questions We Should Ask Ourselves in Order to Avoid Failures When Treating Gunshot Wounds of the Knee Joint

After having dealt with the questions regarding gunshot wounds of the hip joint (Vol II/p 1159) and gunshot fractures of the femur (Vol II/p 1502) the following questions should also be asked

1 Have I at once removed loose bone splinters in injuries to the bones of the knee?
2 Have I, in the presence of slight damage to the skin, inserted a drain and sutured the wound?
3 Have I used antibiotics locally and generally?
4 Have I performed an early joint resection in comminuted fractures with wounds threatened by infection?
5 Have I performed early amputation in comminuted fractures with large wounds and rupture of the popliteal artery?
6 Have I omitted suture of the wound in early amputation?
7 Have I performed secondary suture 5—6 days later, if the wound was clean and the temperature normal?
8 Have I applied a plaster hip spica in those cases in which amputation was not carried out
9 Have I widely opened the suprapatellar pouch in empyema of the joint?
10 Have I in tenderness of the popliteal space, excised the posterior portions of the condyles and established capsular windows?

Course of Gunshot Wounds of the Knee Joint and Their End-results

Mortality Of Jimeno Vidal's[1] 433 cases 30 (6 9%) died, namely, three from gas gangrene, three from septic hemorrhage, one from pulmonary abscess, nine from acute and fourteen from chronic septicemia

Amputation Among his 433 patients 11 patients have survived amputation (2 5%)

Functional Results Of the 392 survivors, in whom amputation was not done, 85 (19 7%) had an ankylosed knee, 72 (16 7%) had a range of motion of 10° to 45° 94 (21 7%) had a range of 45° to 110°, and 141 (32 4%) a range of more than 110°

Wustmann[2] treated from 1941 to 1944 not less than 662 gunshot wounds of the knee joint Within the first 18 months he treated 288 patients without resection by mere drainage and immobilization, 8 (2 8%) of these patients died and 12 (4 2%) had to be amputated In the following two years he performed resection in severely infected knee joints Of 374 patients of this series 10 (2 8%) died and 12 (3 2%) had to be amputated Thus the results were about equal with both methods

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1 Jimeno Vidal Kniegelenkschusse (Erfahrungen aus dem spanischen Burgerkrieg 1936—1939) Arch f Orth u Unfall Chir *41* 649—684 1941

2 Wustmann Zentralbl f Chir 72 1186—1190 1948

88 FRACTURES OF THE LOWER LEG BONES

Classification The following fractures may occur in the region of the lower leg

1 Fracture of the tibial spine (eminentia intercondyloidea),
2 Fracture of one condyle of the tibia,
3 Fracture of both condyles of the tibia,
4 Separation of the upper epiphysis of the tibia,
5 Separation of the tibial tubercle,
6 Isolated avulsion fracture of the proximal end of the fibula,
7 Infracondylar fracture of the leg bones,
8 Fracture of the shaft of the tibia alone,
9 Fracture of the shaft of the fibula alone,
10 Fracture of the shafts of both tibia and fibula,
11 Supramalleolar fracture of the leg bones, either without involvement of the joint, or with a fracture line into the joint but without displacement of the joint surfaces,
12 Compression fracture of the distal end of the leg bones with or without displacement of the surfaces of the ankle joint,
13 Separation of the distal epiphyses of the tibia and fibula,
14 Pronation fractures of one or both malleoli without displacement,
15 Pronation fractures of one or both malleoli with partial or complete dislocation of the foot,
16 Supination fractures of one or both malleoli without displacement,
17 Supination fractures of one or both malleoli with partial or complete dislocation of the foot,
18 Fractures of both malleoli with anterior marginal fracture of the tibia,
19 Fractures of both malleoli with posterior marginal fracture of the tibia

89 FRACTURES OF THE TIBIAL SPINE

Origin Fractures of the tibial spine (figs 2271—2278, 2315—2320) as a rule result from *overextension of the knee joint* i e, when a violent force acts directly on the front of the knee This leads to tearing of the posterior ligaments of the joint and overstretching of the anterior cruciate ligament with avulsion of its bony insertion at the tibial plateau

When a violence acts against the front of the upper end of the tibia, *the knee being flexed* to about right angles, overstretching of the posterior cruciate ligament will result Thus its posterior bony insertion may be avulsed from the tibia and displaced towards the center of the joint Sometimes this fragment is rotated through 180°

Physical examination is carried out as described on pages 1507—1512

Diagnosis Usually the joint is markedly swollen and distended with blood There is marked limitation of extension to 150° to 170° Flexion is also limited Accurate diagnosis of this injury depends on exact AP and lateral roentgenograms



2315 June 27 1928 2316

Fig 2315 —*Avulsion of the entire tibial spine produced by a pig running between the* patient s legs while his foot was fixed The knee joint was overextended and forced laterally Roentgenogram one hour after the accident

Fig 2316 —Same from the side The tibial spine is elevated The knee can only be extended to 170° actively or passively Under local anesthesia it was easy to produce full passive extension of the knee The lateral roentgenogram then showed that the separated bone fragment had been pressed back into its correct place Plaster cast at a position of 180° for seven weeks



2317 *August 22 1928* *2318*

Figs 2317 2318 —Same case after eight weeks Fracture has united in good position Decalcification especially in the patella Four months after the injury the knee had recovered its normal range of motion The patient was a 50 year old butcher

Complications If these fractures are not recognized and reduced, persistent limitation of extension of the knee will result (figs 2319, 2320)

Treatment *As in all fractures of bones treatment consists in reduction* immobilization and exercise





2319 October 7, 1931, 2320

Figs 2319 2320—Avulsion of the anterior cruciate ligament together with a large fragment of bone seven months after a skiing accident The injury was not recognized elsewhere in spite of several roentgenograms The large separate bone fragment was consistently overlooked because the X ray pictures were either unclear or had been taken with inexact positioning of the knee and the tube Most of the lateral exposures were not made exactly laterally but instead were taken in more or less rotation The patient 20 years old had been treated for a sprained knee for seven months by hot air massage and diathermy She had 20° limitation of extension and could move the knee between 160° and 110°





2321 November 4 1931 2322

Figs 2321 2322—Same case eight weeks after removal of the avulsed piece of bone It was removed through a small anterior oblique incision such as is used for a meniscus operation In the anterior view the lower margin of the unusually low patella cuts across the tibial spine In the lateral view the shadow seen in fig 2320 has disappeared Patella decalcified by long immobilization Plaster cast was applied for four weeks after operation Two months later active motion of the knee was restored and there was a slightly positive anterior drawer sign In such cases it would be better to deepen the bed of the avulsed piece and to put the piece of bone back into its correct place and fix it with a U shaped wire suture through two bore holes in the front of the upper end of the tibia

Time of Reduction The earlier reduction is carried out, the more easily it can be performed It will, as a rule, no longer be possible as late as 10 days after the injury

Reduction After the joint cavity has been anesthetized by an injection of 20 ml of a 2% Novocain solution, the blood effusion is withdrawn through a

wide-bore puncture needle Then the joint is slowly extended to 180°

Roentgenograms, made exactly from in front and also exactly from the side, will, as a rule, show complete reduction of the fragment

Immobilization As described on pages 1514—1516 a plaster cylinder is applied at a position of extension at 180° and not in overextension or flexion

Second Roentgen Check is carried out to confirm whether the knee joint is extended to 180° and not overextended or flexed, and whether the good position of the fragments has been retained in the plaster cast

Inscription of the Plaster Cast The lateral pre reduction roentgenogram is sketched on the cast over the fracture site The day of the injury, application of the cast and of its planned removal, as well as the name of the doctor are also inscribed

Splitting the Cast If the check X-rays show good position of the fragment at extension of the knee to 180°, the plaster cylinder is at once split completely to avoid disturbing the circulation of blood

Positioning the Leg The leg with the cast is placed on an oblique splint or a pillow The fore-foot is suspended in a triangular bandage (fig 2641)

Re-application of the Plaster Cylinder When the swelling has disappeared after 6 to 8 days, an Unna's paste dressing is applied over the foot and distal third of the lower leg, and a new plaster cylinder is applied from the ankles to the hip (for technique see pp 1514—1516 and figs 2175—2177) This cast will not be split

Third Roentgen Check After application of the second cast roentgenograms are again made exactly from in front and exactly from the side to see whether the joint shows a position of 180° and is neither flexed or overextended

Exercises As soon as the plaster has set, the patient can start walking In the first week he should walk a total distance of at least 1 km a day but not all at once, increasing the distance by 1 km each week, *if this causes no pain* In addition he should practise raising the leg to a horizontal position while standing to strengthen the thigh muscles The exercises of the whole body should not be omitted

Period of Immobilization The plaster cylinder should remain for six weeks

Further Treatment After removal of the plaster cylinder new roentgenograms are made exactly from in front and especially accurately from the side Then a new Unna s paste dressing is applied from the web of the toes up to the knee (see Verbandlehre [1] pp 74—86) An elastic bandage is worn round the knee during the day The joint becomes mobile with exercises on the knee flexion apparatus (Vol II/figs 1574, 1575) Application of radiant heat or diathermy will promote healing Over-heating is harmful At a later date light sports, including swimming, will be expedient as long as these exercises do not increase the swelling of the joint

Energetic massage and forceful passive movements are always harmful as they irritate the joint and lead to swelling and effusion, thus preventing improvement of joint mobility

All exercises that cause pain are harmful (see Vol I/p 45)

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[1] Bohler L Verbandlehre Vienna Maudrich

Results of Treatment These will be satisfactory, if reduction is complete, if uninterrupted immobilization is maintained for a long enough period, and if exercises are carried out The joint, as a rule, becomes freely mobile after four to eight weeks, and walking is no longer impeded

OLD FRACTURES OF THE TIBIAL SPINE

Operative Reduction In fractures of the tibial spine older than 10 days, extension alone generally will not suffice to replace the fragment, because its bed has been filled with blood clots, fibrous tissue or callus The knee joint should be opened as for a meniscus operation (see p 1597), or through a 5 to 6 cm long medial parapatellar incision On opening the joint, one is surprised to find that the piece of bone so clearly visible in the roentgenogram (figs 2319, 23320) cannot be seen It is only by palpation of the tibial plateau that the movable piece of bone can be felt, and it becomes visible only after cutting through its synovial covering Two to six weeks after the accident the piece of bone may be replaced into its bed by pressure with an elevator, and it will remain in position of itself without any suture or fixation If the operation is done more than six weeks after the accident, the fragment is thickened and deformed, and the hollow from which it was avulsed is filled with callus, so that replacement is no longer possible In such a case the fragment should be elevated and its bed in the tibial plateau should be deepened Then two holes are drilled reaching the front of the tibia at the level of the tibial tubercle and a 1 mm thick stainless steel wire is threaded over the fragment beneath its synovial cover, so that the wire does not come to lie in the joint cavity The ends of the wire are pulled out through the drill holes Then the fragment is accurately replaced and the two wire ends are tied up in front of the tibial tubercle Now the anterior drawer sign will be negative

Prior to closure of the wound *roentgenograms* should be made exactly from in front and exactly from the side to confirm complete reduction of the fragment Then joint and skin are closed Formerly we used to excise the fragment (figs 2319—2322) On reviewing those cases we found that some of these joints were unstable in the sagittal plane

Immobilization, application of the plaster cast, X-ray control and further treatment are carried out as in recent fractures of the tibial spine (see page 1642)

If the *posterior cruciate ligament* is *avulsed and displaced,* thereby greatly interfering with bending of the knee, the knee is exposed by a long posterior incision, through which the peroneal nerve is displaced laterally, and the tibial nerve and the vessels medially Here too the bed in the tibial plateau is deepened until the avulsed piece of bone fits well into its bed Then two holes are drilled toward the front of the tibia The fragment is fixed by a stainless wire suture in the same way as in anterior avulsion

X-ray control immobilization application of the plaster cast and further treatment are carried out as in recent fractures of the tibial spine (see page 1642)

Questions We Should Ask Ourselves in Order to Avoid Failures When Treating Fractures of the Tibial Spine

1 Have I, in a case with markedly limited extension, obtained exact AP roentgenograms with the central ray tilted 5° to 10° distally (fig 2263) and also exact lateral views?
2 Have I taken a second lateral roentgenogram if the first one was oblique?
3 Have I extended the knee to 180° under local anesthesia?
4 Have I made new roentgenograms exactly anteroposteriorly and especially accurately from the side to confirm complete reduction of the fragment?
5 Have I, after the roentgenogram confirmed complete reduction of the fragment, applied a plaster cylinder from the ankle to the hip, to retain the good position?
6 Have I, after application of the plaster cylinder, made new roentgenograms exactly from in front and especially accurately from the side to demonstrate that the position of the fragment has remained good in the plaster cast, and to see if the joint is at 180° and not overextended or flexed
7 Have I at once split the plaster cylinder completely to avoid pain and/or disturbed circulation?
8 Have I, when the swelling has disappeared, i e , after 6 to 8 days, applied a new closed plaster cylinder?
9 Have I, after application of the plaster cylinder, made new roentgenograms exactly from in front and exactly from the side, as in question 6?
10 Have I, after application of the plaster cylinder, told the patient to walk 1 km every day in the first week but not all at once, increasing the distance by 1 km in each following week, if this causes no pain?
11 Have I told the patient to raise his leg to the horizontal position several times a day to strengthen the quadriceps?
12 Have I removed the plaster cylinder six weeks after the accident?
13 Have I after removal of the plaster, made new roentgenograms exactly from in front and especially accurately from the side?
14 Have I, after removal of the plaster cylinder, applied an Unna s paste dressing from the web of the toes up to the knee and an elastic bandage round the knee?
15 Have I protected the patient from massage, passive movements and overheating?
16 Have I omitted all motion and exercises which cause pain?

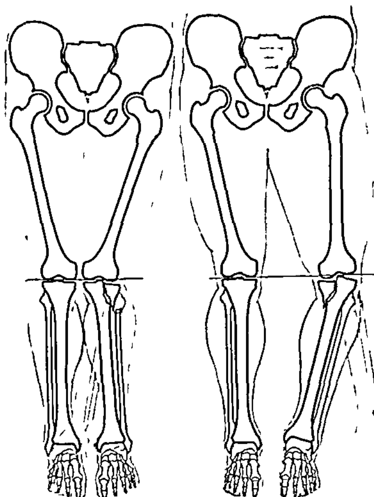
90 FRACTURES OF THE UPPER END OF THE TIBIA

Types of Fractures and Displacements In the upper end of the tibia either or both condyles of the tibia may be fractured

There are two different types of fractures of the lateral condyle Either the main fragment is tilted and compressed (figs 2323, 2324 a—c, 2325—2333) or the condyle is split In the latter type the central part of the articular surface is depressed between the main fragments (figs 2324 d—f, 2334—2341, 2347 a) Depressions 1 to 5 mm deep in the central part of the articular surface

without further damage to the condyle are the initial stage of this type of fracture and are called egg shell fractures About 40% of all fractures of one condyle show no appreciable displacement

In *lateral tilting or compression fractures* the joint surface is intact while under it the lamellae of the cancellous bone are impacted In fractures of the



2323 Sketched in February 1931 2324

FIG 2323 —Compression fracture of the lateral condyle of the tibia and of the head of the fibula Both fragments displaced downwards Lower leg in valgus position Cf fig 2324 a

FIG 2324 —Shearing fracture of the medial tibial condyle The fragment is displaced downwards The lower leg in varus position Cf figs 2366 2367

lateral condyle with severe tilting the head of the fibula is fractured (figs 2324 a, 2329—2331) Usually then the entire lateral condyle is involved The tibial spine is not infrequently included with the lateral fragment Sometimes the lateral half of the lateral condyle is broken off and is in varus position (figs 2324 b 2342) In other cases a long lateral fragment is sheared off vertically and displaced caudally (fig 2324 c)

Medial tilting or compression fractures are much less common than those of the lateral side (figs 2365, 2367) Usually we have seen only fissures or minimal displacement

In the second type of fracture, the *split fracture,* the tibial condyle is split longitudinally. The detached marginal fragment may be wide (figs. 2324 d, e, 2334—2337) or narrow (figs. 2324 f, 2338—2341, 2347 a). The central and posterior part of the articular surface is depressed 10 to 30 mm. between the main fragments. The anterior wall of the condyle usually remains intact. Split fractures without displacement of the central and/or posterior part of the articular surface are rare. Even in these fractures the medial part of the lateral articular surface is tilted (fig. 2324 d).

In *bicondylar fractures,* both condyles are broken off the tibial shaft. The fracture lines either traverse the condyles or the metaphyseal region (diacondylar, figs. 2351—2355 h). There may be an associated fracture through the upper part of the tibial shaft (infracondylar fracture, figs. 2356—2363). Some diacondylar fractures are impacted (figs. 2355 a, 2355 e) whereas all infracondylar fractures are not impacted (figs. 2356, 2357). They appear as Y- or T-shaped fractures in the anteroposterior roentgenogram. The condyles are merely tilted towards each other (figs. 2355 a, 2355 c, 2355 e), or they are at different levels (figs. 2356, 2360). The lateral or medial condyle may be dislocated in relation to the femur (figs. 2354, 2360).

The lateral roentgenogram shows recurvation (figs. 2355 a, 2355 e, 2357) or antecurvation (figs. 2355 c, 2355 g, 2361). The AP view may show varus or valgus. Diacondylar fractures with recurvation are as a rule associated with posterior subluxation (fig. 2355 e), those with antecurvation usually show anterior subluxation (figs. 2355 g 2361). In infracondylar fractures subluxation does not occur (fig. 2357).

Origin of Fractures of the Upper End of the Tibia

Compression fractures of the lateral condyle (fig. 2324 a) generally result from a vertical fall with the knee extended, mainly in elderly people with decalcified bones, e. g. when jumping off the street car or off a chair, or by indirect violence, i. e. through a fall with a bicycle or motorcycle. Due to the normal valgus position of the knee joint the force acts more strongly on the lateral tibial condyle forcing its lateral edge downwards. Nowadays this type of fracture is frequently found in persons who, with the knee extended, are hit by the bumper of an automobile from the side just below the knee joint. The body is thrown against the car, and the leg buckles sideways at the knee joint. As a result the lateral femoral condyle forces the lateral tibial condyle downward. In severe displacement, even the head of the fibula is broken (figs. 2324 a, 2329—2331). The mechanism of the fracture, is a combination of bending and impaction. The lateral collateral ligament is slackened, the medial one *is usually preserved because the axis of the bend passes through* the middle of the joint or through the medial part of the joint and thus exerts only little leverage on the medial collateral ligament. Simple rupture of the medial ligament without bone fracture occurs from bending or buckling of the leg in the frontal plane (see p. 1565) without accompanying axial impaction. The axis of the bend then passes through the lateral portion of the joint. Isolated tears of the medial collateral ligament are usually seen in people with normal calcium content.

Fractures of the lateral condyle alone with varus of the fragment (figs 2324 b, 2342) probably result from impaction and torsion in which the iliotibial band produces the varus position of the fragment

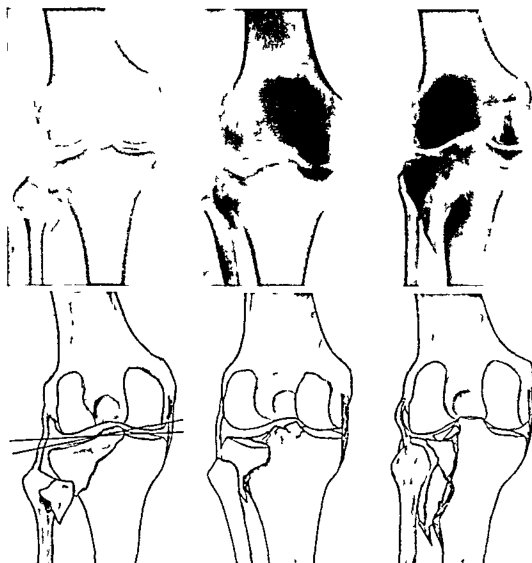
Compression fractures of the medial condyle result from a violent force acting on the medial side of the knee In one of our patients a heavy stack of iron sheets fell against the lateral side of the lower limb He sustained a split fracture of the left lateral tibial condyle (fig 2324 f) and a compression fracture of the right medial tibial condyle, since the left lower limb was forced into a marked valgus position and the right one into a varus position

Split fractures of the lateral condyle with or without depression (figs 2324 d—f) result from impaction in the long axis and valgus angulation with the knee more or less flexed Flexion of the knee is associated with external rotation of the lower leg If, moreover, an increased valgus position overstretches or tears the medial collateral ligament (fig 2324 d), lateral subluxation of the upper end of the tibia will result Thus, with increasing flexion the lateral margin of the femur moves away more and more from the lateral margin of the tibia In slight flexion of the knee a violent force acting from above and laterally will split a small marginal fragment from the tibial condyle (fig 2324 f), in more pronounced flexion of the knee a fragment with a broader brim (fig 2324 d, e) will be split off The width of the lateral fragment will largely depend on the amount of lateral subluxation of the tibia at the moment of trauma The greater the subluxation, the bigger will be the marginal fragment

We have never observed *split fractures of the medial condyle*, but the medial condyle, together with the tibia spine may be depressed in a case of a split fracture of the lateral condyle (fig 2354) in which the medial rather than the lateral condyle is separated from the tibia

Fractures of both tibial condyles may result from different kinds of trauma A vertical fall from a height may cause at first a fracture of one condyle If the force continues to act the metaphyseal region of the contralateral side will, in the case of brittle bones, be fractured (fig 2355 c) The compact tibial shaft gets wedged between the condyles, forcing them apart (figs 2351—2355) The impact of a heavy object, e g, a gravestone as in fig 2355 a, on the anterior aspect of the extended knee causes a fracture of both condyles with recurvation of the fragments The same thing happens when the bumper of an automobile hits the front of the upper end of the tibia (bumper fracture) Recurvation also results when the upper end of the tibia — with the knee flexed — hits against an obstacle, e g the I-beam of a railing, as in figs 2355 e, 2357 Ehalt[1] described such cases If the force strikes the front of the upper end of the tibia just below the joint, a wedge-shaped fragment is broken out anteriorly (fig 2355 e), if the force acts more distally the bone wedge will be detached at the level of the tibial tuberosity (fig 2357) This wedge splits the upper end of the tibia in the sagittal plane Varus (fig 2355 c) or valgus angulation (fig 2356) may occur depending on whether the violent

[1] Ehalt W Trummerbruche am oberen Schienbeinende mit gleichzeitiger Zerreißung des Lig patellae proprium als typische Motorradverletzung (Traversenverletzung) Monatsschr Unfallheilk *44* 417—427 1937



2324 a
44 cases (14 1%)

2324 b
11 cases (3 6%)

2324 c
16 cases (5 2%)

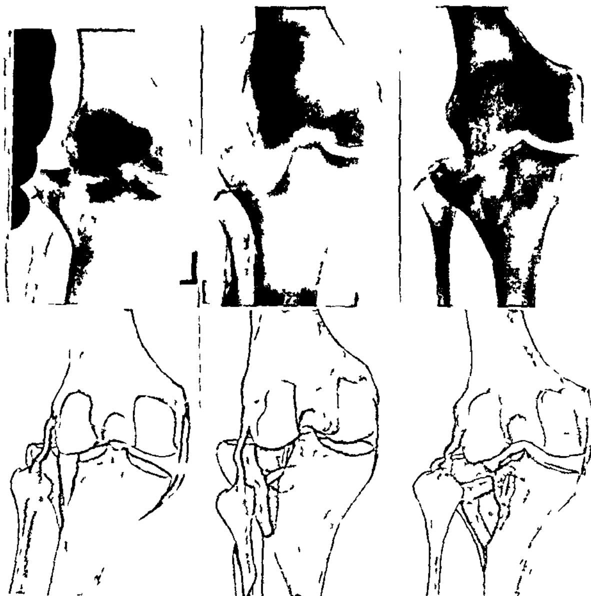
FIG 2324 a —Compression fracture of the lateral tibial condyle and fracture through the head of the fibula Valgus displacement between the tibial fragments the head of the fibula is subluxated Valgus at the knee joint 15⁰ Sustained by a 56 year old servant who fell from a chair

FIG 2324 b —Compression fracture of the lateral tibial condyle Varus displacement between the tibial fragments Normal valgus of 7⁰ at the knee joint Sustained by a 36 year old unskilled worker who fell with his bicycle

FIG 2324 c —Shearing fracture of the lateral tibial condyle Valgus of 10⁰ at the knee joint Sustained by a 50 year old locksmith who was hit by a crane load

The roentgenograms 2324 a—e are reproduced from Ender s paper Behandlung und Behandlungsergebnisse der Schienbeinkopfbruche Arch orthop Unfall chir *47* 130—145 1955

force hits the anteromedial or the anterolateral side of the upper end of the tibia In severe shortening of the tibia with valgus angulation the head of the fibula is dislocated cranially If the tibial shaft becomes displaced still further posteriorly than is shown in fig 2357 the sharp upper edge of the distal



2324 d
3 cases (1/)

2324 e,
20 cases (6 55/)

2324 f
37 cases (12 1/)

FIG 2324 d — The lateral part of the left lateral tibial condyle has been split off the medial part has been depressed and tilted downward so that articular surface faces lateralward Rupture of the medial collateral ligament Valgus of 25⁰ Sustained by a 30 year old unskilled worker in whom the lateral side of the left thigh was hit by a heavy steel plate At the same time he suffered a tilted fracture of his right medial tibial condyle These lateral condylar fractures can be reduced by adduction of the lower leg and lateral compression of the displaced fragment

FIG 2324 e — A broad marginal fragment has been split off the lateral tibial condyle The central part of the articular surface has been depressed between the main fragments Angulation fracture of the fibula Valgus of 20⁰ Normal width of the medial joint space These fractures can usually be reduced by adduction of the lower leg and forceful lateral pressure on the big fragment Open reduction is seldom necessary

FIG 2324 f — A relatively small marginal fragment has been split off the lateral tibial condyle The central part of the articular surface is comminuted and depressed The fibula has been widely displaced Valgus of 20⁰ In this type of fracture with narrow marginal fragment the meniscus is frequently torn loose at its base and depressed between the fragments Sustained by a 60 year old female who fell in the street This type of fracture usually requires operative treatment The above roentgenogram is taken from a publication of Salem and Wurnig (Die Gelenksfrakturen am oberen Tibiaende und ihre Behandlung Arch orthop Unfall chir 45 600–616 1953) This case was reduced without open operation and a good result was obtained

fragment may tear the popliteal artery or more distally the anterior or the posterior tibial artery or both (fig 2378 a)

In a fall with the knee slightly flexed, as in figs 2355 c, 2355 g, or when a heavy load rolls over the thigh with the knee slightly flexed, the posterior part of the upper end of the tibia becomes sheared off (posterior shearing fracture) and split apart This may be associated with a fracture of the fibula and cranial subluxation of the lateral or medial tibial condyle

Concomitant Injuries Rupture of the popliteal artery above its bifurcation is rare If it occurs, it will cause gangrene of the lower leg if the torn segment cannot be replaced by a graft from the blood-vessel bank If only the anterior tibial artery is torn the lower leg will usually remain viable

Injuries of the peroneal nerve are rare If the nerve has only been stretched it will usually recover its function soon afterwards *If it is torn, paralysis is* usually permanent since in most cases suture is impossible

Rupture of the Collateral Ligaments In split fractures of the lateral condyle the medial collateral ligament may be torn (fig 2324 d)

Rupture of the cruciate ligaments is rare

Rupture of the patellar ligament or avulsion of the lower pole of the patella may occur in injuried caused by I-beams (figs 2356—2358)

Injuries of the Menisci In split *fractures with a small marginal fragment* the meniscus may be torn at its base partly, seldom completely, and displaced between the fragments The narrower the marginal fragment, the deeper the depression, and the wider the separation of the fragments, the more likely is such displacement The meniscus as such is not torn, as a rule In some posterior shearing fractures it sometimes is ground to bits

Physical Examination of the Fractures of the Upper End of the Tibia Inspection usually discloses a more or less marked swelling with or without angulation In rupture of the popliteal artery the foot is pale and cold, it is blue when vessels are compressed The dorsalis pedis and posterior tibial pulses must be investigated to exclude injuries to or diseases of the vessels The patellar tendon reflex on the sound side is tested and the pupils are examined for reaction to light and convergence Active motion of the toes, of the subtalar and of the ankle joints are examined and compared with the sound side Sensation is tested The stability of the knee is tested cautiously, avoiding pain

Roentgen Examination To read the films properly one must keep in mind that in a normal AP view the articular surfaces of both condyles of each, the femur and the tibia, lie at right angles to the tibial shaft, and that there is a valgus of 7° to 10° between the femoral shaft and the vertical axis of the tibia The lateral view shows downward posterior slope of the tibial articular surface of 7° to 10° To detect individual variation roentgenograms should be taken on the sound side for comparison For accurate measurement of the valgus angle the roentgen films should be at least 24 cm long At least 8 cm of the femur should be included in the roentgenogram Accurate diagnosis of a lesion of a collateral ligament or of the different types of fracture in this region depend on roentgenograms taken exactly from the front and exactly from the side For accurate positioning of the knee local anesthesia is needed in

most cases If the roentgenogram of the joint space is obtained obliquely, the resulting distortion may lead to incorrect diagnosis In fractures with antecurvature the central ray must be directed at a sufficiently oblique angle to the knee joint (fig 2263) The correct angle can be taken from the lateral picture

Most disturbances following fracture of the upper end of the tibia result from angulation of the fragments Angulation must therefore be looked for in the radiograms In the normal AP picture a (horizontal) line drawn through the center of the joint space runs parallel with both the femoral and tibial condyles (figs 2326, 2331) A line drawn parallel to a tilted tibial condyle runs obliquely through the joint space and crosses the opposite femoral condyle (figs 2325, 2329, 2330, 2355 c, 2355 e) To determine these lines we do not draw a line in the film, but use a transparent celluloid ruler As has been said before, in fractures of the upper end of the tibia the normal valgus angle between the femoral and the tibial shafts must be considered (fig 2355 e) as well as the posterior slope of about 10° of the tibial articular surface Assuming that in a fracture of the upper end of the tibia with recurvation the tibial articular surface slopes 5° forwards, the real recurvation angle will amount to 5° plus 10° = 15° (figs 2355 a, 2355 e) In the absence of accurate measurement this angulation is frequently underestimated or overlooked

Diagnosis of Fractures of the Upper End of the Tibia Valgus deformity is more frequent in these fractures than varus deformity If the fragments are displaced abnormal motion can be elicited In most fractures of both condyles with displacement crepitation can be felt, but this is absent in compression fracture of a single condyle Pain and severe swelling are usually present and weight-bearing is impossible Blebs may soon develop Differential diagnosis between fracture of one condyle and rupture of a collateral ligament may be difficult without roentgenograms Fractures of the upper end of the tibia are often overlooked, or their severity is underestimated, because angulation (mainly the varus deformity) is frequently misjudged In the case shown in figure 2366 the radiologist stated the limb was straight In the photographs (figs 2365, 2366) a considerable varus deformity can be seen

Complications Following Fractures of the Upper End of the Tibia Rupture of the main arteries cause gangrene of the leg Most disturbances result from angulation, namely, varus, valgus, recurvation or antecurvation Angulation may also cause loosening of the joint If angulation is not corrected, painful arthrotic changes and limited motion will develop later on Steps in the articular surface give surprisingly little trouble

Avoidance of Complications Complications can be avoided if these fractures are reduced accurately and immobilized for a long enough period and if exercises are performed

Questions We Should Ask Ourselves in Order to Avoid Failures in Suspected Fracture of the Upper End of the Tibia

A General questions They are the same as in examination of dislocation of the hip (see Vol II/p 1088)

B Questions regarding the upper end of the tibia

1 Have I inquired about the past history and about the details of the accident?
2 Have I noted any discoloration of the injured limb (pale or cyanotic instead of normal)?
3 Have I noted the presence of swelling of blebs or a deformity of the knee or lower leg as well the type of the latter (valgus or varus, recurvation or antecurvation, internal or external rotation)?
4 Have I examined for abnormal mobility?
5 Have I made roentgenograms exactly from in front and exactly from the side?
6 Have I chosen at least 24 cm long roentgen films and adjusted them so that they showed at least 8 cm of the femur?
7 Have I made roentgenograms of the well knee of the same length for comparison?
8 Have I adequately inclined the central ray for the AP roentgenogram (fig 2263)?
9 Have I applied a transparent celluloid ruler to the joint space in the AP roentgenogram to determine whether one or both condyles are at their normal level
10 Have I measured the angle between tibial shaft and articular surface in the lateral roentgenogram to determine the degree of any antecurvation or recurvation (figs 2355 a, 2355 c, 2355 e)?
11 Have I written down all findings immediately?

Principles of Treatment in Fractures of the Upper End of the Tibia

The object of treatment is to obtain a straight limb with a knee joint which is firm, can bear weight well has full extension and the maximum possible range of flexion

If, after a severe fracture of the upper end of the tibia, the knee is laterally stable and has *full extension* although flexion is less than 90° such a joint is by far preferable to a fully mobile knee with lateral instability It is not the number of degrees of motion that is important but *where* this range of motion lies A range of motion between 180° and 140°, i e 40° of motion, is preferable to 90° of motion if the range of motion lies between 160° and 70°

It is, moreover, not always necessary to obtain a completely even joint surface Shallow depressions are of no importance in the presence of a broad marginal fragment which ensures sufficient stability

In unicondylar tilted fractures in which there is angulation but no shortening correction of the valgus or varus is achieved by bending (figs 2323, 2324) If the depressed condyle remains displaced it is lifted with Steinmann pins (figs 2333, 2347) In split fractures with depression and a broad marginal fragment the lateral condyle — after previous correction of the valgus — is pressed back into its place manually or with the bone compression clamp (Vol I/fig 137) In many of the cases with but a small marginal fragment open reduction with elevation of the depressed fragment implantation of bone chips and the use of screws are necessary In bicondylar fractures where shortening is frequent, the latter must first be overcome by means of the screw

traction apparatus In cases with antecurvature slight pressure is exerted in front and a long leg cast, with the knee extended, is applied as well as continuous traction Treatment will be continued in a long leg walking cast Diacondylar fractures with recurvation are reduced in the screw traction apparatus After correction of the shortening the knee is at first strongly *flexed* over the surgeon s forearm placed in the popliteal space and then *extended* to an angle of 150° In this position a long leg plaster cast is applied Further treatment consists in continuous traction followed by a long leg walking cast

Operative treatment is often necessary in the unicondylar split fractures when there is only a small marginal fragment Bicondylar fractures can, as a rule, be successfully reduced by manipulation

Treatment of Fracture of the Upper End of the Tibia Without Displacement

A plaster cast is applied from the tips of the toes up to the hip and split completely at once When the swelling of the knee has subsided 5 to 7 days later, a long leg walking cast is applied for five more weeks

Treatment of the Unicondylar Tilted Fracture With Valgus (Fig 2324 a) or Varus (Fig 2366) Deformity

Time of Reduction These fractures should be reduced within the first day after injury as the displaced fragments tend to stick together in the following days, thus impeding reduction

Local Anesthesia If the fracture site has not yet been anesthetized for the roentgen examination, 20 ml of a 2% Novocain solution are injected The blood effusion can be withdrawn at the same time

Reduction The roentgenograms are displayed so that the surgeon can refer to them at all times during the reduction Then the lower leg is adducted in a fracture of the lateral condyle (figs 2323, 2324 a, 2325—2328) and abducted in a fracture of the medial condyle (fig 2324) Thus the correct axis of the limb is restored Since the joint capsule has remained intact in these fractures, it pulls the tilted medial or lateral condyle upwards into its correct position At the same time the relaxed collateral ligament is tightened Overcorrection, as shown in figure 2328, must be avoided Longitudinal traction is not necessary for reduction as there is only angulation of the fragments without shortening

First Roentgen Check After reduction both tibial condyles must lie in the same plane, whereas after the fracture they formed an angle which was distally open (figs 2325—2328)

Reduction of the Fracture with Steinmann Pins If adduction alone fails to lever up the tilted condyle, one should use two Steinmann pins (figs 2329 to 2333) for this purpose Insertion of the pins is described in detail on pp 1658, 1659 In tilted fractures however, the pins must be lifted, and not lowered, as in figure 2344

Reduction with the Bone Compression Clamp If the fracture cannot be reduced even with two Steinmann pins, a well-padded bone compression clamp (Vol I/fig 137), as it is used for fracture of the os calcis may be employed

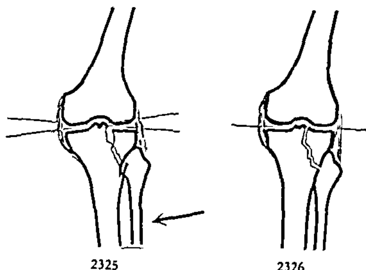


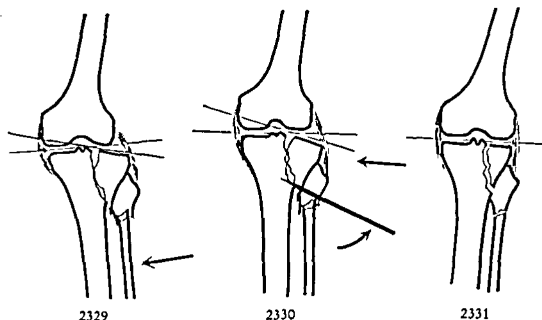
Fig 2325—Fracture of the lateral tibial condyle Fragment displaced downward and tilted Lower leg in valgus position Reduction is carried out by adduction of the lower leg

Fig 2326 The valgus deformity has been corrected The intact lateral collateral ligament is tightened by the adduction of the lower leg and presses the broken fragment upwards and medially Thus the angulation with *the angle concave distally is corrected*



Fig 2327—*Compression fracture with tilting of the lateral tibial condyle before reduction* Sustained by a 46 year old man who fell from a height of 4 M into an elevator shaft

Fig 2328 - Same case after reduction The valgus position has been corrected by adduction of the lower leg The articular surfaces of the two tibial condyles are once more on the same level After relieving *the overcorrection at the distal end of the fracture a plaster cylinder* was applied and split at once One week later a long leg cast was applied to the lower limb for seven more weeks Union in good position with full functional recovery



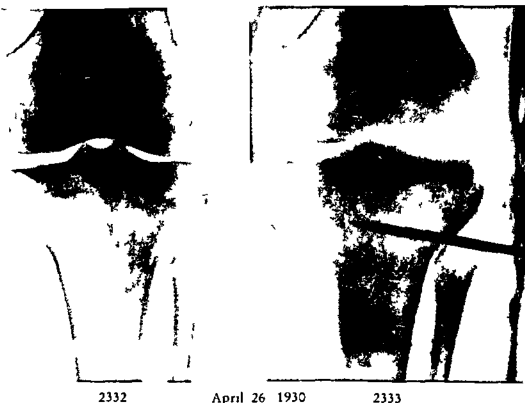
2329 2330 2331

Sketched June 1928

Fig 2329 —Compression fracture with tilting of the lateral tibial condyle and impaction fracture of the head of the fibula Marked displacement of the fragments The collateral ligaments are intact

Fig 2330 —The valgus position has been corrected by adduction of the lower leg Because the fracture surfaces are caught on one another the head of the fibula and the lateral tibial condyle have not been drawn up The latter is levered up with a Steinmann pin and pressed into place manually or with the calcaneus clamp It is better to use two pins since a single pin cuts through in some cases

Fig 2331 —After reduction by the above method



2332 April 26 1930 2333

Fig 2332 —Fracture of the lateral tibial condyle The joint line is lower on the lateral than on the medial side Angulation with a distally open angle The lateral joint space is narrowed Increased valgus position

Fig 2333 —Same case after reduction The lower leg was adducted and the displaced condyle levered up by a pin Both articular surfaces at the same level The lateral joint space is of normal width Usually it is better to insert two pins to lever up the fragments

It is applied in such a way that one pad comes to lie below the tilted tibial condyle and the other above the opposite condyle of the femur

In all our cases of fresh tilted fractures of one tibial condyle reduction with one of these three methods was successful within the first two weeks after injury Open operation was not necessary

The Use of a Strong Hemp Cord to Facilitate Splitting of the Plaster Cast If the roentgenogram shows satisfactory position, one end of a 6 to 7 mm hemp cord 100 cm long is knotted and the knot is placed into the plantar side of the second interdigital space The cord is placed over the dorsum of the foot and the anterior aspect of the lower leg, closely lateral to the anterior border of the tibia over the center of the patella and the thigh, in order to split the cast along this cord without touching the skin with the plaster knife

Application of the Plaster Cast A plaster cast is applied over the hemp cord from the tips of the toes up to the hip The patient is positioned as shown in figure 2175

Formerly we only applied a plaster cylinder leaving the foot free A cylinder does not, however, give sufficient support to prevent re angulation

Application of the Plaster Cast in the Screw Traction Apparatus He who has little practice in the freehand application of a plaster cast should after insertion of an os calcis pin fix the limb in the screw traction apparatus and treat the case as a fracture of both condyles (pp 1671—1673) This will avoid re-displacement of the fragments during application of the plaster cast

Second Roentgen Check After application of the cast new roentgenograms are taken from both sides to confirm whether the good position of the fragments has been maintained

Splitting the Cast If the roentgenograms show good position of the fragments the cast is at once split throughout its full length along the inserted cord

Placing of the Leg The leg is placed on an oblique splint or a pillow The fore-foot is suspended to protect it from rotation

Application of the Walking Cast After 8 to 14 days when the swelling has completely disappeared, a walking cast from the tips of the toes to the hip is applied either without support or in the screw traction apparatus This plaster cast is not split If the plaster has been applied in the screw traction apparatus the os calcis pin is now removed

Third Roentgen Check After application of the walking cast roentgeno grams should again be taken exactly from the front and exactly from the side In the AP roentgenogram accurate measurement should be made to exclude any valgus or varus deformity If in doubt, an AP roentgenogram of the uninjured side should be made for comparison The lateral roentgenogram must prove that the joint is in full extension of exactly 180° and neither overextended nor flexed

Application of the Walking Stirr p As soon as the plaster cast has hardened and the roentgenograms show good position a walking stirrup is applied

Exercises When the plaster cast is dry the patient can start walking In the first week he should walk a total distance of at least 1 Km a day but not all at once, increasing the distance by 1 Km each week, *if this causes no pain*

In addition he should practice raising the leg several times a day to strengthen the thigh muscles The exercises of the whole body should not be omitted

Fourth Roentgen Check Two weeks after application of the walking cast new roentgenograms should be made

Duration of Immobilization The walking cast is removed 7 to 8 weeks after the injury depending on the amount of the original displacement

Further Treatment After removal of the walking cast a fifth roentgen check is made to confirm the position of the fragments, the firmness of the fracture and the calcium content Then an Unna's paste dressing is applied from the webs of the toes to the knee (see "Verbandlehre", pp 74—86) An elastic bandage is worn round the knee at daytime Joint motion is regained by exercises on the knee flexion device (Vol II/figs 1574, 1575) The exercises are performed for 5 minutes twice a day and extended by 5 minutes every day to a maximum period of 45 minutes, if this causes no pain and no swelling Application of heat favors good healing Overheating must be omitted In addition, exercises of the whole body are carried out

Massage and passive movements are always harmful since they irritate the joint and cause swelling and joint effusion which impair the progress of joint mobility

Exercises must not cause pain (see Vol I/p 45)

Questions We Should Ask Ourselves in Order to Avoid Failures in the Treatment of Unicondylar Tilted Fractures of the Upper End of the Tibia

1 Have I determined from the roentgenograms the type of fracture (unicondylar tilted fracture, unicondylar split fracture with large or small marginal fragment, bicondylar fracture with antecurvation or recurvation)?

2 Have I reduced it as early as possible, preferably on the first day after injury?

3 Have I adducted (abducted) the lower leg in unicondylar tilted fractures of the lateral (medial) condyle to widen the joint space and to lift the condyle by tightening the joint capsule?

4 Have I made new roentgenograms after correction of the angulation to check the success of reduction (do both femoral lie parallel to both tibial condyles?)

5 Have I attempted to lift the tilted fragment with two Steinmann pins, if reduction was not achieved by mere correction of angulation?

6 Have I tried to elevate the tilted fragment — after previous correction of the angulation — with the well padded obliquely placed calcaneus compression clamp, if reduction with the two Steinmann pins has failed?

7 Have I placed a 1 M long, 6 to 7 mm in diameter hemp cord on the anterior side of the limb to facilitate splitting the plaster cast, when the post-reduction roentgenograms showed good position?

8 Have I, after insertion of the cord applied a plaster cast from the tips of the toes up to the hip with the knee extended, and not only a plaster cylinder as shown in figure 2175?

9 Have I driven a pin through the calcaneus and fixed the limb in the screw traction apparatus if I have not had sufficient practice in applying the cast freehand?
10 Have I, when using the screw traction apparatus, applied the plaster cast only after the roentgenograms had shown good position in both planes and after the cord had been placed on the front of the limb?
11 Have I made new anteroposterior and lateral roentgenograms after application of the plaster cast to check whether the good position has been maintained?
12 Have I at once completely split the plaster cast along the inserted cord?
13 Have I elevated the limb on an oblique splint or pillow after the plaster had been split?
14 Have I applied a long leg walking cast (without support or in the screw traction apparatus) 8 to 14 days after reduction?
15 Have I made new roentgenograms exactly from the front and exactly from the side after application of the walking cast and compared them with those of the uninjured side?
16 Have I removed the calcaneus pin after application of the cast in the screw traction apparatus if the roentgenograms showed good position?
17 Has the patient performed appropriate exercises (walking — if no pain is caused, raising the limb to horizontal)?
18 Have I removed the plaster cast 7 to 8 weeks after the injury?
19 Have I made new roentgenograms after removal of the cast?
20 Have I — after removal of the cast — applied an Unna s paste dressing from the webs of the toes to the knee and an elastic bandage round the knee during the daytime?
21 Has the patient practiced on the knee flexion device twice a day 5 minutes *to start with, increasing the daily period of exercise by 5 minutes daily* to a total amount of 45 minutes if this causes no pain and no swelling?
22 Has the injure kee been protected from overheating and chilling?
23 Have massage and passive motion been avoided?

Treatment of the Unicondylar Fracture of the Upper End of the Tibia with a Cranially Tilted Fragment (figs 2324 b 2342—2344)

This relatively rare fracture cannot be reduced by mere adduction The displaced fragment can however be levered into place by two sterile Steinmann pins

Insertion of the First Pin After the fracture and the skin have been anesthetized a sterile Steinmann pin is driven 3 cm deep into the lateral condyle at a point 2 to 3 cm distal to the joint space The pin should lie parallel to the joint space

First Roentgen Check After insertion of the pin an AP roentgenogram is made to confirm its correct position In figure 2323 the pins were inserted too far distally, in figure 2344 they were not driven in parallel to the joint space

Use of the Rapid Developer A rapid developer should be used to get the roentgenograms quickly (see Vol II/p 1253)

Insertion of the Second Pin If the roentgenogram shows good position of the first pin, another pin is driven in 1 cm distal and parallel to the first one In all cases two pins should be used since a single pin might easily cut through the fragile cancellous bone

Reduction of the Fracture If these two pins are tilted distally during adduction of the lower leg the fragment is lifted into its proper place

Second Roentgen Check Another AP roentgenogram must be made to determine whether the position of the fragment is good

Deeper Insertion of the Two Pins In the case of good position of the fragment both pins are driven in another 3 to 4 cm to avoid re-displacement during application of the plaster cast

Application of the Plaster Cast The cast is applied from the tips of the toes up to the hip as shown in figure 2175 The patient need not be placed in the screw traction apparatus since the fragment has been fixed by the two pins

Removal of the Two Pins When the plaster cast has set the pins are removed to avoid infection and formation of a draining sinus

Splitting the cast, application of the subsequent walking cast, exercises, roentgen checks, duration of immobilization and *further treatment* are carried out as for tilted fractures on pp 1656 and 1657

Treatment of the Unicondylar Shearing Fractures (Fig 2324 c)

An attempt is first made to reduce these fractures by adduction of the lower leg as in tilted fractures (see p 1653) If this fails to reduce the fracture, the sheared off lateral (fig 2324 c) or medial condyle (fig 2347) should be lifted by two Steinmann pins as described on page 1658 The pins should in this case be lifted without tilting to avoid tilting the fragments Further treatment is the same as described above

Treatment of the Split Fractures of the Upper End of the Tibia with a Broad Marginal Fragment (Figs 2324 d, e)

As regards *time of reduction* and *local anesthesia*, the same applies as in tilted fractures (see p 1653)

Adduction of the lower leg corrects the valgus position and reduces the fracture In this way the lateral femoral condyle is raised from the depression between the tibial condyles (figs 2334, 2335) Then both tibial condyles are powerfully pressed together manually or with the calcaneus compression clamp (Vol I/fig 137) When using this compression clamp care must be taken to have the knee well padded, especially on the lateral aspect, to avoid harmful pressure on the peroneal nerve

The first *check roentgenogram* usually shows that the upper end of the tibia is no longer broadened or only slightly so and that the head of the fibula has regained its proper position, whereas the depressed part of the joint surface lies still wedged between the main fragments (fig 2336) At a follow-up examination in this case eleven years later there were no significant arthrotic changes and the functional result was good In spite of eventual slight broadening of the upper end functional recovery will as a rule be satisfactory if angulation has been corrected



2334 April 19 1937



2336 April 19 1937



2335 April 19 1937



2337 April 1 1948

FIG 2334—Fracture of the lateral tibial condyle with a broad marginal fragment split off and depression of the central part of the articular surface as in fig 2324 e The lateral part of the lateral tibial condyle is subluxated laterally and tilted so much that the tip of the fibular head lies at the level of the joint space Sustained by a 44 year old locksmith who jumped from a 50 cm high step Roentgenogram made in forced abduction

FIG 2335—Check roentgenogram re fig 2334 made in forced adduction The valgus deformity has disappeared The lateral anterior and posterior parts of the lateral condyle have regained their proper position whereas the center part is still depressed 1 cm The upper end of the tibia is still broadened

FIG 2336—Check roentgenogram re fig 2335 after lateral compression of the upper end of the tibia by calcaneus compression clamp The transverse diameter of the upper end of the tibia has been diminished by 5 mm Application of a plaster cylinder which was split at once Eight days later a long leg walking cast was applied for seven more weeks

FIG 2337—Check roentgenogram re figs 2334—2336 eleven years later Bony union of the fragments Laterally stable joint Joint mobility 180° to 50° as on the sound side Slight marginal exostosis of the medial femoral condyle The central depression in the lateral tibial condyle causes no disturbance because the anterior lateral and posterior edges have been preserved Asymptomatic Works again as a locksmith



2338 December 11 1934



2340 December 11 1934



2339 December 11 1934



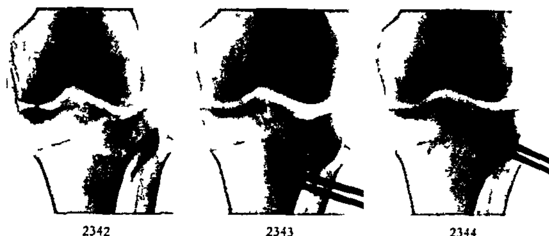
2341 September 19 1935

FIG 2338—Fracture of the lateral tibial condyle with a narrow marginal fragment split off (as on fig 2324 f) and depression of the central part of the joint surface The lateral part of the joint surface is subluxated laterally and tilted so far down that the tip of the fibular head lies at a higher level than the joint space Sustained by a 42 year old civil servant who was hit by a car at the lateral side of his thigh Roentgenogram in forced abduction Valgus 25°

FIG 2339—Check roentgenogram re fig 2338 in forced adduction The valgus deformity has been corrected The lateral edge of the tibia is split off and markedly tilted laterally The major part of the lateral condyle is depressed The head of the fibula is again in its correct position

FIG 2340—Check roentgenogram re fig 2339 An attempt to pull up the depressed piece of bone with a pin has failed

FIG 2341 Check roentgenogram re fig 2339 nine months later The depressed piece of bone is again in its right place It has been levered up at open operation and held in its correct position by two tibial grafts The upper end of the tibia is slightly broadened Joint mobility 180° to 60° Normal gait Stable joint Asymptomatic at a follow up after 12 years



2342 2343 2344

June 12 1938

FIG 2342—Fracture of the lateral tibial condyle sustained by a 36 year old unskilled worker who fell from a bicycle The lateral half of the lateral condyle has been tilted medially as in fig 2324 b

FIG 2343—Check roentgenogram re fig 2342 after insertion of two nails They lie too far distally

FIG 2344—Check roentgenogram re fig 2342 after insertion of two new pins They pierce the fragment By lowering the pins the fragment has been completely reduced There was normal motion and stability of the joint at a follow up examination five years later No arthrotic changes



2345 May 9 1935

Specimen of a fracture of the lateral tibial condyle in a 31 year old man who died a few hours after the accident due to other severe injuries The meniscus is severed from its anterior attachment but not torn in its substance It would therefore not be excised

The use of the hemp cord the application of the plaster cast with or without screw traction apparatus the second Roentgen check, splitting of the cast, placing of the limb in plaster application of the walking cast the third Roentgen check the exercises and further treatment are carried out the same way as in the tilted fractures (see pp 1656, 1657)

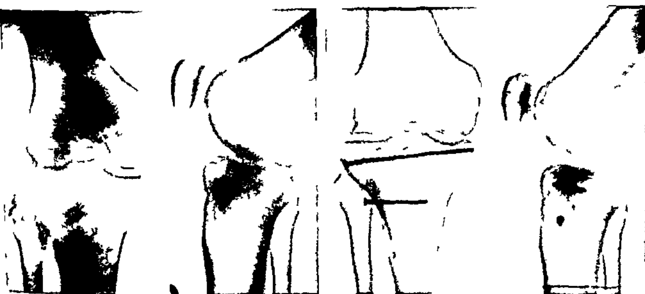
Operative Treatment of Fracture of the Upper End of the Tibia in Which a Big Marginal Fragment is Split Off As a rule, the normal axis of the limb



2346 November 25 1926 2347

FIG 2346 — Comminuted fracture of the upper end of the tibia The medial tibial condyle is displaced 2 cm downward Sustained by a 42 year old female in an automobile accident

FIG 2347 — Check roentgenogram re fig 2346 The lower leg was abducted and the medial condyle levered up by a percutaneous transfixion pin



2347 a January 21 1951 2347 b July 12 1953

FIG 2347 a — Fracture of the lateral tibial condyle with a comparatively narrow marginal fragment split off as in fig 2324 f The posterior margin of the tibial plateau is intact A 10×15 mm piece of bone from the central part of the joint surface has been depressed by 30 mm The lateral femoral condyle has been wedged into the upper end of the tibia Valgus of 20° Sustained by 33 year old skier who hit a tree

FIG 2347 b — Check roentgenogram re fig 2347 a two and a half years after open reduction The fracture was exposed through an anterior longitudinal incision The anterior wall was hinged forward the depressed piece of bone was lifted to joint level and propped with a tibial bone graft The meniscus which was loosened from the capsule and diplaced into the fracture cleft was replaced and stitched to the joint capsule The lateral tibial margin was secured with two screws As a rule one screw is sufficient At the follow up examination external shape and color of the knee were normal Asymptomatic Joint mobility 180° to 50° as against 180° to 40° on left side Rotation free Lateral stability of the joint Can participate in all sports

can be restored by adduction of the lower leg and the broadening of the upper end of the tibia can be corrected by compression. If this is not possible the joint must be exposed to lift the depressed fragment (see below).

Treatment of Fracture of the Upper End of the Tibia in Which a Small Marginal Fragment is Split Off (Fig. 2324 f)

In most fractures with a small marginal fragment split off, compression of the upper end of the tibia will not suffice to achieve a stable joint since in this type of fracture the remaining edge, especially with the knee flexed, does not provide sufficient stability and since the meniscus is often severed from the capsule and displaced into the fracture cleft. The depressed fragment cannot be levered up even with pins (fig. 2340).

Operative Treatment of Fracture of the Upper End of the Tibia with a Small Marginal Split Off. If the general condition is good and the skin normal, the knee joint is exposed under spinal or general anesthesia. The operation is performed in a bloodless field through an anterolateral longitudinal incision. After severance of skin and fascia the displacement of the fragments cannot yet be seen in most of the cases. Only after transverse incision of the joint capsule (below the cartilage) can one detect that the anterior edge of the condyle has remained intact, whereas the lateral edge has been tilted outward. The central and posterior parts of the articular surface have been depressed for 1 to 3 cm and wedged into the spongy bone (figs. 2324 f, 2338—2340). In half of our cases of open reduction the meniscus was partly severed and only seldom completely severed from the capsule and displaced into the fracture space. In order to gain a good view of the fragments and the joint the anterior wall is broken loose and tilted anteriorly and the lateral fragment tilted laterally. A meniscus severed from the capsule and displaced between the fragments is replaced and secured with 2 to 3 stitches. The fibrous capsule is pierced at first from outside, the base of the meniscus is caught and then the needle leaves the joint piercing the capsule again. The sutures are not tied until the bone fragments have been reduced. The depressed part of the joint surface is lifted with a bone elevator. The split off fragment which has been tilted laterally is pressed towards the upper end of the tibia while the lower leg is adducted. The elevated central fragment is propped up in its right place by a sufficiently big bone graft taken from the patient's tibia or iliac crest or from the bone bank. In some cases the central part of the articular surface is comminuted so badly that it must be removed. It is then replaced by a piece of the iliac bone. After insertion of the bone the upper end of the tibia is once again compressed manually with both hands or with a sterile calcaneus compression clamp. Then the sutures through the capsule and the base of the meniscus are knotted and the ventrally tilted anterior wall of the condyle replaced.

First Roentgen Check. Roentgenograms from the front and the side are made to determine whether the limb is straight and whether the elevated articular surface, the inserted graft and the split off marginal fragment are *in* good position and the upper end of the tibia is no longer broadened.

Screwing of the Fragments. If the roentgenograms show satisfactory position of the fragments, a 6 to 8 cm long screw is inserted 1 cm below the joint surface

In some cases a second screw is necessary (fig 2347 b) The screws serve to hold the fragments together for 8 to 10 weeks until bony union has been achieved It is therefore superfluous to add washers and nuts If these four metal pieces are not of the same alloy, electric current will develop and corrode the metal The chemical irritation will cause arthrosis Formerly we used to compress the fragments and not to secure them with screws (fig 2341)

Second Roentgen Check New roentgenograms are made after insertion of the screws to see whether they are placed well (fig 2347 b) If not, they must be taken out and replaced by new ones

Closure of the Wound and Application of a Compression Bandage If the roentgenograms show good position of the fragments and the screws, capsule and skin are closed Penicillin is given locally and for a few days systemically Then a sterile cord is placed on the front of the lower limb as described on page 1656 and over it a compression bandage is applied

Critique of Removal of the Meniscus At present most surgeons remove the meniscus when treating fractures of the upper end of the tibia by open reduction, no matter whether the meniscus has been severed from the capsule or torn or has remained uninjured As we have described on p 1605, we consider the meniscus a very important part of the knee joint, especially following fractures of the upper end of the tibia, since it smooths the uneven joint surface We have, therefore, never removed the meniscus but rather have replaced it If the meniscus was torn we excised the avulsed portion only Danger of a subsequent tear is cited as a reason for total excision of the meniscus We have never yet seen a meniscus tear after a healed fracture of the upper end of the tibia, nor have we heard or read of such a case

Application of the plaster cast, roentgen check, splitting the cast and *positioning the limb* are carried out as described on page 1656

Walking cast and *walking stirrup* should not be applied after one week but after four weeks The walking cast is removed ten weeks after the injury

Exercises and *further treatment* are carried out as described on pages 1656 and 1657

Questions We Should Ask Ourselves in Order to Avoid Failures in the Treatment of Unicondylar Split Fractures of the Tibial Condyle

1 Have I determined in the roentgenogram whether a broad or a narrow marginal fragment has been split off?
2 Have I tried, in the case of a broad marginal fracture, to correct the angulation by adduction of the lower leg and pull the lateral femoral condyle out of the fracture cleft?
3 Have I compressed the broadened upper end of the tibia with both hands or the calcaneus compression clamp after correction of the angulation?
4 Have I in split fractures with a small marginal fragment, exposed the fragments under general or spinal anesthesia and in a bloodless field if the patient s general condition has been good and his skin normal?
5 Have I refrained from removing a meniscus severed from the capsule and displaced downward and put it back into place and secured it with stitches?
6 Have I excised only the avulsed portion of a torn meniscus?

7 Have I elevated the central and dorsal parts of the articular surface and propped them up with a piece of bone from the ipsilateral tibia, the iliac crest or the bone bank
8 Have I compressed the laterally displaced marginal fragment with both hands or with the calcaneus compression clamp?
9 Have I, after compression of the lateral fragment, made roentgenograms to see whether the depressed piece of bone, the bone graft and the lateral fragment show good position?
10 Have I secured the fragment with only one simple screw and not with washers and nuts to avoid electric current and metal corrosion?
11 Have I obtained new roentgenograms after insertion of the screws?
12 Have I carried out further treatment as for tilted unicondylar fracture if the roentgenograms showed good position after insertion of the screw, and have I answered the questions nos 7 to 22 on pages 1657 and 1658?
13 Have I applied the long leg walking cast not earlier than four weeks after operation?
14 Have I removed the walking cast not earlier than 10 weeks after the accident?

Treatment of Bicondylar Hyperextension Fractures With Recurvation (Figs 2351—2355, 2355 a, b, 2355 e, f, 2356—2359)

Treatment of Shock Bicondylar fractures of the upper end of the tibia are usually much severer injuries than unicondylar fractures and may by associated with severe shock Shock treatment has been described in Vol II/p 1089

Time of Reduction Formerly we reduced some of these fractures as late as 8 to 10 days after the marked swelling had subsided As displaced fragments are often stuck together in an unsatisfactory position after this time and no longer yield to longitudinal traction we have, since 1935, performed reduction on the very first day if possible

For *reduction maintenance of the position* and *further treatment* the following are required

1 Local anesthesia,
2 Good AP and lateral roentgenograms (fig 2355 g, h),
3 A stainless Steinmann pin 15 cm long and 4 mm in diameter (Vol I/figs 129—136) for the upper end of the tibia and another pin or a wire for skeletal traction at the calcaneus,
4 A hammer to drive in the pin (Vol I/fig 127),
5 A rotating stirrup for the pin or a traction clamp for the wire (Vol I/figs 129—131),
6 A hand drill (Vol I/figs 132 133) an electric (Vol I/figs 134—136) or a pneumatic drill (Vol II/figs 1696—1699) to insert the wire,
7 A support for back and head (Vol II/fig 1576)
8 A screw traction apparatus for the leg with supplementary piece (Vol I/figs 103—105, figs 2348 and 2349) or any other extension apparatus,
9 A foot sling (fig 2348),

10 Spring scales (Vol I/fig 139),
11 A folded pad, 0 5 × 10 × 18 cm ,
12 A calico bandage 10 cm by 120 cm with wooden tongue blades sewn in, The tongue blades are sewn in to avoid wrinkling of bandage and subsequent pressure,
13 A wooden spreader, 2 × 10 × 25 cm (Vol I/fig 148),
14 A calcaneus compression clamp (Vol I/fig 137) with large pads,
15 Two felt pads, 8 × 8 × 1 cm ,
16 Mastisol,
17 Cotton tipped applicators (Vol I/fig 152),
18 A strip of flannel 5 × 70 cm (fig 2175),
19 Eight 17thread plaster bandages, 5 m × 15 cm , weighing 400 grams (see Vol I/p 115),
20 A lower leg splint (Vol I/fig 111, fig 2350) or an oblique frame with a pulley (fig 2350 a),
21 A bed with firm support (boards under the mattresses) (Vol I/figs 9, 100 fig 2350),
22 A wooden box, 25 × 40 cm , for the sound foot (Vol I/fig 118, figs 2350 2350 a),
23 A 6—7 mm in diameter hemp cord,
24 Six weights of 1 Kg each (Vol I/fig 118, figs 2350, 2350 a),
25 A radiant heat cradle to warm the bed and to dry the plaster cast,
26 Wooden gallows (Vol I/figs 117, 118, fig 2350 a)

The original roentgenograms, not sketches, are displayed so that the surgeon can always refer to them during the reduction

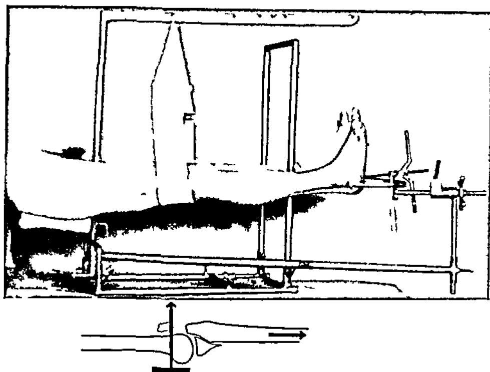
Local Anesthesia of the Fracture Site The site of the fracture is anesthetized by injection of 20 ml of a 2% Novocain solution if this has not been done before the roentgenograms were made Marked effusion of blood should be relieved by aspiration

Local Anesthesia of the Pin Sites On the medial and lateral side of the heel, two finger-breadths posterior and distal to the tips of the malleoli the spots are marked with the bare end of the cotton-tipped applicators where the pin (wire) is to be driven (drilled) through These two sites are painted with iodine and each site is anesthetized with 10 ml of a 2% Novocain solution

Insertion of the Pin The pin is driven with a hammer through the calcaneus and a rotating stirrup is applied Special caution must be taken that the pin does not lie too close to the tips of the malleoli as this may lead to injury of nerves vessels and or tendons (tibialis post , flexor hall long , flexor dig long) at the medial side, and/or to injury of the peroneal tendons at the lateral side Piercing the subtalar joint with the pin or wire is especially dangerous as infection of this joint may develop (figs 2765—2767) Even in absence of infection, injury of the cartilage or metal corrosion may cause arthrotic changes (figs 2387—2389) later on, when a pin, wire or clamp lies in a joint for a prolonged period of time

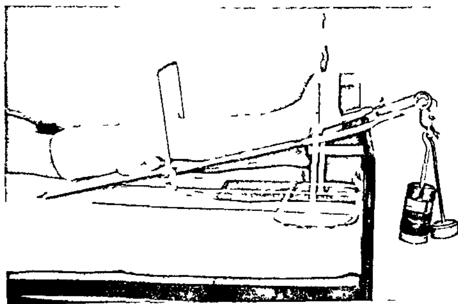
A wire may be used instead of the pin for skeletal traction

Correction of Recurvation with Wedged Fragments Recurvation without shortening as in some diacondylar fractures (figs 2355 a, 2355 e) is corrected by



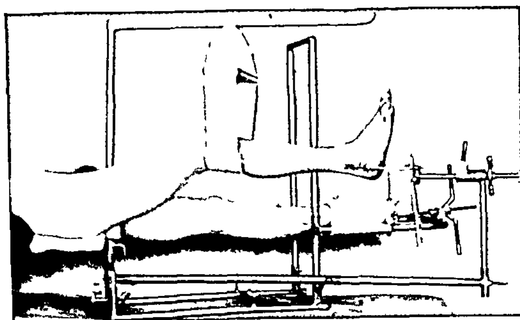
2348

Positioning of a bicondylar *flexion* fracture with antecurvature on the screw traction apparatus under local general or spinal anesthesia The well foot is fixed with a sling to the foot plate The fractured limb is suspended *proximal* to the extended knee joint with a 10 cm wide cotton bandage which is held wrinkle free by sewn in wooden spatulae Inside the cotton bandage lies the 0 5 × 12 × 18 cm pad The two strips of the cotton bandage are kept apart by the 2 × 10 × 15 cm wooden spreader to avoid lateral pressure on the lower end of the thigh A pin or wire is driven through the calcaneus and connected with a stirrup to a spring scale The latter is attached to a screw apparatus for traction of 8 to 10 Kg



2349

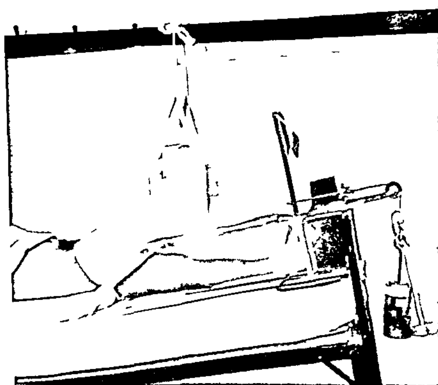
Positioning on an oblique frame of a reduced *flexion* fracture of the upper end of the tibia after application of the plaster cast with the knee extended Continuous traction of 6 Kg To avoid rotation the foot of the plaster cast is suspended on the transverse bar of the oblique frame *The plaster cast must be split immediately* to avoid circulatory disturbances The sound foot is propped against a wooden box





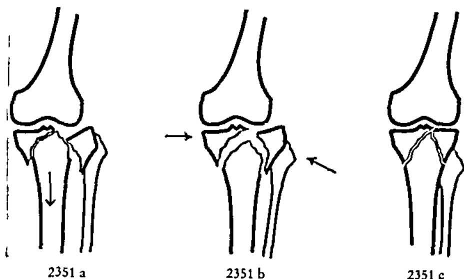
2350

Positioning of a bicondylar *hyperextension* fracture with recurvation (posterior bowing) the knee flexed at 150° The padded cotton bandage is held apart by a wooden spreader The sling is placed *distal* to the knee joint under the fracture to avoid re angulation following reduction of the fragments Otherwise the positioning and applicaion of the cast is the same as in a flexion fracture (see fig 2348)



2350 a

Positioning on a Braun splint of a reduced *hyperextension* fracture of the upper end of the tibia after application of the cast The knee is flexed to 150° Continuous traction of 6 kg The lower end of the bed is raised 30 cm The footplate of the cast is suspended to avoid rotation The well foot is propped against a wooden box *The plaster cast must be split immediately throughout its full length* to avoid circulatory disturbances The cast is suspended under the calf with a wide belt on a gallows to avoid recurrence of recurvation

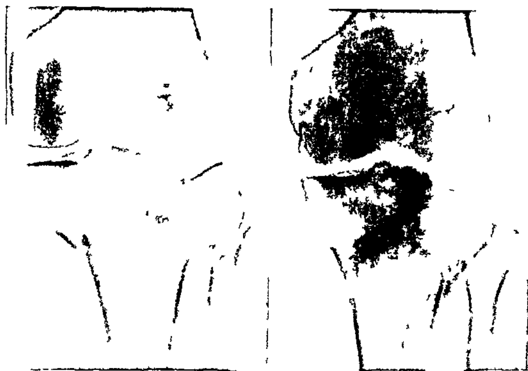


sketched in February 1929

Fig 2351 a – Fracture of both tibial condyles The shaft of the tibia is driven up between the condyles separating and displacing them The condyles cannot be reduced until the shaft has been drawn down

Fig 2351 b —The shaft is drawn down by axial traction this leaves the space between the condyles free

Fig 2351 c Fragments and joint restored to normal position by axial traction on the tibial shaft and by powerful compression of the condyles



2352 June 25 1929 — 2353 October 23 1929

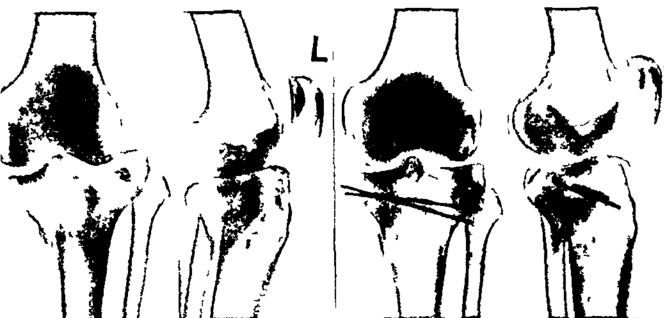
Fig 2352 —Fracture of both condyles of the tibia with separation of the fragments The shaft is deeply wedged between the condyles Sustained by a 62 year old mason who fell 2 M from a scaffolding

Fig 2353 —Same case after four months Reduction was achieved by strong axial traction and compression of the condyles Fixed in a plaster cast for 6 weeks while traction was maintained Walking plaster for a further six weeks Union in good position Movements from 180° to 60° No lateral instability

strong flexion of the lower leg over the fulcrum of the surgeon's forearm in the popliteal space (figs 2355 a, b, 2355 e, f)

Correction of Shortening Shortening, as shown in figs 2351—2355, 2356, 2357, must first be overcome by calcaneus pin traction with the knee flexion of 150°, as shown in Vol II/fig 2166 c

Positioning of the Leg on the Screw Traction Apparatus After insertion of the pin the foot sling is put on the sound foot Then the patient is positioned



2354 April 28 1953 — 2355 July 8 1953

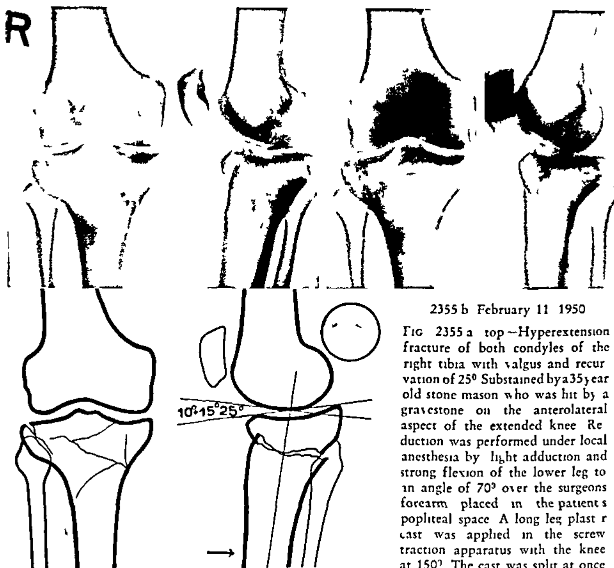
Fig 2354 —Split fracture of the left lateral tibial condyle The fracture line does not separate the tibial shaft from the lateral condyle but from the medial condyle and the tibial spine Lateral subluxation of the lower leg The normal valgus has disappeared The lateral roentgenogram shows the medial condyle sheared off posteriorly whereas the lateral condyle is subluxated anteriorly similar to that in fig 2355 g Sustained by a 43 year old mason who fell with his motorcycle Reduced under local anesthesia in the screw traction apparatus with calcaneus pin traction of 8 Kg the knee being extended After correction of the shortening the fragments were compressed Two stainless wires were drilled through the condyles The long leg cast was split at once continuous traction of 6 Kg was applied for five weeks and was followed by a long leg walking cast for five weeks

Fig 2355 —Check roentgenogram re fig 2354 ten weeks later Bony union in good position The anterolateral subluxation of the lateral fragment has disappeared

on the screw traction apparatus The sound leg is fixed to the foot plate A spring scale is placed between the rotating stirrup and the hook of the traction screw The 0 5 × 12 × 18 cm stitched pad is placed underneath the fracture site The 10 cm wide cotton bandage with the sewn-in wooden tongue blades is placed under this, and the limb is suspended with the knee flexed at 150° to avoid recurvation The two strips of the cotton bandage are kept apart by the 2 × 10 × 25 cm wooden spreader to avoid pressure on the bones (fig 2348)

Reduction By turning the screw, traction is increased up 8 to 10 Kg and the tibial shaft is pulled out from the separated condyles (fig 2351 a) Traction of the joint capsule of the collateral ligaments and of the adjoining tendons

usually reduces the fragments well If not, they are compressed with both hands (fig 2353) Traction in the long axis of the limb, as a rule, corrects a varus (fig 2355 e, f) or valgus deformity (figs 2356—2358) If the varus or valgus



2355 b February 11 1950

2355 a February 19 1946

Fig 2355 a top—Hyperextension fracture of both condyles of the right tibia with valgus and recurvation of 25° Sustained by a 35 year old stone mason who was hit by a gravestone on the anterolateral aspect of the extended knee Reduction was performed under local anesthesia by light adduction and strong flexion of the lower leg to an angle of 70° over the surgeons forearm placed in the patient s popliteal space A long leg plaster cast was applied in the screw traction apparatus with the knee at 150° The cast was split at once and left on without continuous traction for four weeks Finally a long leg walking cast was applied for six more weeks

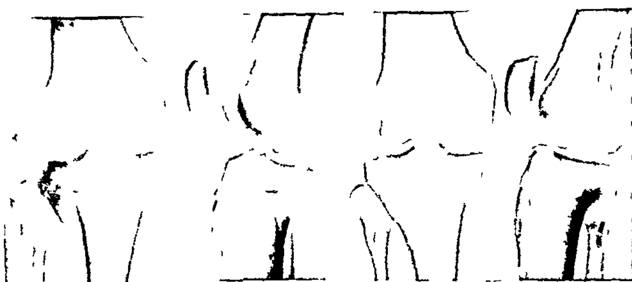
Fig 2355 a bottom Sketch re the above roentgenograms Recurvation amounts to 10° + 15° = 25° Reduction is performed over the fulcrum of the surgeon s forearm placed in the patient s popliteal space by pressure on the anterior side of the lower end of the tibia

Fig 2355 b—Check roentgenogram re fig 2355 a four years later Recurvation (posterior bowing) corrected No arthrosis Joint motion 180° to 60° as against 180 ° to 45° on the left side Asymptomatic

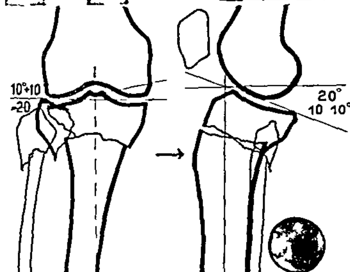
persists the vertical sling is moved slightly laterally or medially Traction in the long axis must not be excessive or the condyles may tilt

First Roentgen Check To check the result of reduction roentgenograms are taken exactly from the front and exactly from the side They usually show

good position of the fragments (figs 2356, 2358) It must be considered that the joint surface slopes 10° down posteriorly in the lateral roentgenogram, whereas it lies at a right angle to the tibial shaft in the AP view



2355 d February 2 1950



2355 c February 7 1948

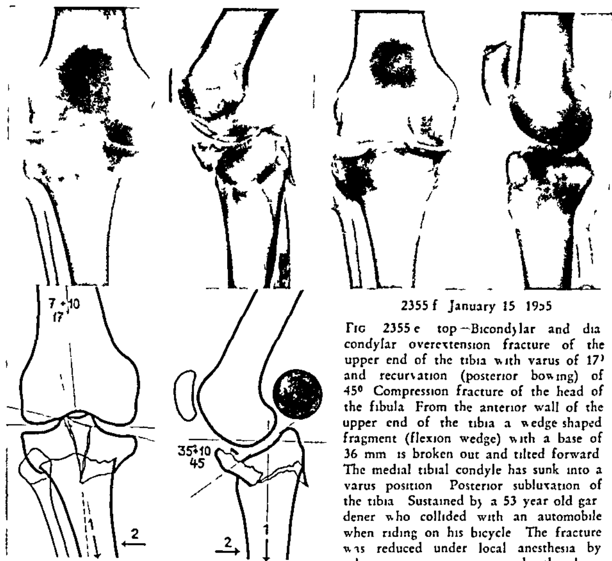
FIG 2355 c top – Bicondylar and infracondylar flexion fracture of the upper end of the tibia with antecurvature and valgus of 20° each The medial part of the lateral tibial condyle has been tilted into valgus the lateral part into varus Compression fracture of the head of the fibula Decalcification of bones Sustained by a 61 year old woman who slipped in the street and fell This probably increased at first the valgus of the extended knee and then led to the infracondylar flexion fracture with antecurvature caused by subsequent rotation and flexion Reduced under local anesthesia by adduction of the lower leg pressure on the anterior side of the fracture and forward movement of the foot Full plaster cast with the knee extended The cast is split at once The patient lies in this cast for four weeks Then a full leg walking plaster is applied for a further four weeks

FIG 2355 c bottom Sketch re the roentgenograms of fig 2355 c top The fragments are impacted posteriorly and gape in front

FIG 2355 d Check roentgenogram re fig 2355 c two years later Antecurvature and valgus have disappeared Full range of active movements of the joints as of the sound leg

Compression of the Upper End of the Tibia with the Calcaneus Compression Clamp If there is still shortening traction is increased If, after correction of the shortening the upper end of the tibia is still broadened in spite of compression of the condyles with both hands felt pads, 8×8 cm and at least 1 cm thick, are placed on both sides Then the condyles are compressed by the broad attachment of the calcaneus compression clamp quickly and strongly (fig 2351 b)

After closing, the clamp should be opened *at once*, lest the skin be injured by undue pressure or paralysis of the peroneal nerve occur I have heard of a case



2355 f January 15 1955

2355 e November 22 1953

Fig 2355 e top —Bicondylar and diacondylar overextension fracture of the upper end of the tibia with varus of 17° and recurvation (posterior bowing) of 45° Compression fracture of the head of the fibula From the anterior wall of the upper end of the tibia a wedge shaped fragment (flexion wedge) with a base of 36 mm is broken out and tilted forward The medial tibial condyle has sunk into a varus position Posterior subluxation of the tibia Sustained by a 53 year old gardener who collided with an automobile when riding on his bicycle The fracture was reduced under local anesthesia by calcaneus pin traction with the knee extended The lower leg was then flexed to 65° over the surgeon s forearm placed in the popliteal space The long leg cast was applied in the screw traction apparatus with the knee at an angle of 150° The cast was split at once Continuous traction with 6 Kg in the split cast followed for seven weeks Finally a long leg walking cast was applied for three more weeks

Fig 2355 e bottom —*Sketches re the roentgenograms of fig 2355* e top The angulations the direction of traction and pressure are shown as well as the fulcrum in the popliteal space

Fig 2355 f —Check roentgenogram re fig 2355 e 14 months later The varus has disappeared Both tibial condyles are at the same level Recurvation (posterior bowing) has disappeared Knee motion 170° to 65° as against 175° to 60° on the sound side

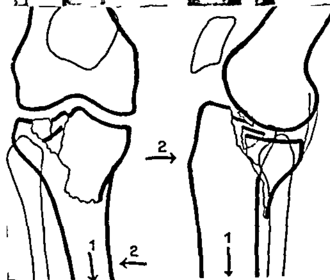
in which deep ulcers developed because the clamp was allowed to remain for twenty minutes while roentgenograms were being taken

Second Roentgen Check In the rare cases in which the compression clamp is used, new check roentgenograms *in both planes are made after its removal*

Immobilization If the roentgenograms show good position of the fragments, the upper end of the thigh is painted with a few strokes of Mastisol Over these strokes a 5 × 70 cm long flannel strip is placed so that both ends meet on the



2355h July 18 1936



2355 g May 8 1936

FIG 2355 g top left —Bicondylar posterior flexion and shearing fracture of the upper end of the tibia with varus of 12° and anterocranial subluxation of the lower leg The medial tibial condyle with the tibial spine has been tilted into a valgus position Sustained by a 48 year old office worker who fell from a ladder Reduction was achieved under local anesthesia in the screw traction apparatus with calcaneus pin traction of 8 Kg The knee was extended the lower leg was slightly abducted After correction of the shortening slight pressure was exerted on the front of the upper end of the tibia Long leg plaster cast which was split at once and continuous traction of 6 Kg for six weeks Then long leg walking cast for four weeks

FIG 2355 g bottom —Sketch re roentgenograms of fig 2355 g top shows displacement of fragments and directions of applied traction and pressure

FIG 2355 h —Check roentgenogram re fig 2355 g ten weeks later The displacements have disappeared The bones have become somewhat dealcified In a follow up examination ten years later the knee was laterally stable and showed no drawer sign Ankle motion 175° to 60° Asymptomatic

lateral side and not in front The strip must not wrinkle A 100 cm long hemp cord is placed on the limb in a way as described on p 1656 A 100—110 cm long splint is made out of two plaster bandages and applied from the tips of the toes to the flannel strip Two circular plaster bandages are put over it Then a plaster splint, 75 cm long is made and cut into three parts of equal

length These plaster splints are applied at the medial, lateral and anterior aspects of the knee joint Two or three circular plaster bandages are wound around and moulded very carefully around the transfixion pin

Third Roentgen Check As soon as the cast has hardened new roentgenograms must be made exactly from the front and exactly from the side

Placing of the Limb on the Lower Leg Splint If the roentgenograms show good position of the fragments the cotton suspension sling is cut off and the limb is placed on a lower leg splint Continuous traction of 6 Kg is applied at the calcaneus pin (fig 2350 a)

Marking of the Plaster Cast The outline of the fracture before reduction, the dates of accident, reduction and subsequent check roentgenogram, and the name of the surgeon are recorded on the cast

The *cast must be split at once* along the cord throughout its full length to avoid circulatory disturbances

Placing of the Patient in Bed As soon as the cast has been split completely, the patient with his lower leg splint is placed in bed Too little traction should be avoided as it leads to renewed shortening and separation of the condyles The wooden box is used for the sound foot The lower end of the bed is raised 30 cm (fig 2350 a)

Suspension of the Plaster Cast When the swelling subsides after a few days, there is danger that the fragments will sink, i e, danger of new recurvation This can be prevented by suspending the plaster cast at the fracture site with a cotton bandage or a belt from the wooden gallows (fig 2350 a)

Closure of the Split Plaster Cast As the swelling of the limb subsides after a few days the plaster cast becomes too loose To avoid angulation of the fragments the cast is closed with a bandage In some cases the edges of the cast are cut off for better apposition

Fourth Roentgen Check After one week new roentgenograms are made in both planes

Re-reduction of the Fracture If the roentgenograms show new shortening angulation and/or broadening of the upper end of the tibia re-reduction must be performed as described on pages 1671—1674 This, however is rarely neces sary if the cast is suspended and longitudinal traction of 6 Kg is applied

Fixation of the Upper End of the Tibia with two stainless steel wires If re-displacement has occurred in spite of (1) good reduction, (2) sufficiently strong longitudinal traction and (3) suspension of the plaster cast two stainless steel wires, 2 mm in diameter should be drilled through both condyles after new reduction to prevent recurring redisplacement of the fragments (fig 2355)

Check Roentgenograms If the roentgenograms again show good position of the fragments and the wires a plaster cast is applied which need not be split

Fifth Roentgen Check Three weeks after the accident new roentgenograms are made in both planes

Removal of the First Plaster Cast Six weeks after the accident the first plaster cast is removed and the firmness of the fracture is cautiously tested

Sixth Roentgen Check This is done to see whether satisfactory position has been maintained and to check the callus formation and the degree of demineralization

Application of the Long Leg Walking Cast With the patient positioned as in figure 2175 a cast is applied with 7 or 8 plaster bandages as described on page 1515 but with inclusion of the foot This cast is not split

Seventh Roentgen Check After application of the walking cast new roentgenograms are made in both planes

Marking of the Cast This cast is also marked as described on page 1676

Exercises are carried out as described on pages 1656

Duration of Immobilization The long leg walking cast is removed ten weeks after the accident

Eighth Roentgen Check After removal of the cast new roentgenograms are made in both planes

Subsequent treatment is performed as described on page 1657

Questions We Should Ask Ourselves in Order to Avoid Failures in the Treatment of Fractures of Both Condyles With Recurvation

1 Have I determined in the roentgenogram whether the bicondylar fracture shows antecurvation or recurvation?
2 Have I anesthetized the sites of the fracture and of the calcaneus pin and driven in the pin?
3 Have I applied the foot sling to the sound foot?
4 Have I corrected the recurvation of wedged-in diacondylar fractures by vigorous flexion of the lower leg over the forearm placed in the popliteal space (fig 2355 a, b)?
5 Have I positioned the patient on the screw traction apparatus after correction of the recurvation and have I suspended the injured limb with a padded and wrinkle-free cotton bandage? Has the knee of the injured limb been flexed to 150°?
6 Have I inserted the wooden spreader between the two strips of the cotton suspension bandage?
7 Have I corrected the shortening by longitudinal traction of 8 to 10 Kg (fig 2352)?
8 Have I avoided excessive longitudinal traction of more than 10 Kg which would otherwise cause tilting and overcorrection of the condyles?
9 Have I compressed the condyles with both hands after correction of the shortening?
10 Have I made roentgenograms exactly from the front and exactly from the side after compression of the condyles?
11 Have I, in unstable fractures, drilled one or two 2 mm stainless steel wires transversely through the upper end of the tibia to avoid re displacement of the condyles (fig 2355)?
12 Have I made new roentgenograms in both planes after insertion of the wires to confirm their good position?
13 Have I after placing a hemp cord on the anterior aspect of the limb, applied a plaster cast from the tips of the toes to the hip if the position of the fragments and the wires was good?
14 Have I obtained new roentgenograms in both planes after application of the cast?

15 Have I placed the limb on a lower leg splint and exerted traction of 6 Kg at the calcaneus pin (fig 2350 a)?
16 Have I split the plaster cast along the cord at once and throughout its full length?
17 Have I inscribed the plaster cast?
18 Have I raised the lower end of the bed by 30 cm ?
19 Have I suspended the cast at the site of the fracture on the wooden overhead gallows (fig 2350 a)?
20 Have I closed the split cast with a bandage when the swelling has subsided after three or four days?
21 Have I made new roentgenograms after one week?
22 Have I repeated reduction and application of a plaster cast with continuous traction of 6 Kg if the roentgenogram shows displacement?
23 Have I obtained roentgenograms in both planes after application of the new plaster cast?
24 Have I inscribed the new plaster cast?
25 Have I obtained new roentgenograms after three weeks?
26 Have I removed the cast and continuous traction six weeks after the injury?
27 Have I cautiously tested the firmness of the fracture after removal of the cast?
28 Have I obtained new roentgenograms in both planes to see whether the good position has been maintained, and to check the callus content and the degree of demineralization?
29 Hawe I applied a long leg plaster cast after having cautiously extended the knee?
30 Have I obtained new roentgenograms exactly from the front and the exactly from the side after application of the cast?
31 Have I applied a walking stirrup when the roentgenograms show good position?
32 Have I inscribed the walking cast?
33 Have I had the patient carry out the exercises as described on page 1656?
34 Have I removed the walking cast ten weeks after the accident?
35 Have I continued the treatment after removal of the walking cast as for a tilted unicondylar fracture (see questions 19 to 23 on p 1658)?

Treatment of Flexion Fractures of Both Tibial Condyles With Antecurvation (figs 2355 c d 2355 g, h, 2360—2363)

Treatment of shock local anesthesia, insertion of the calcaneus pin and positioning the limb on the screw traction apparatus are carried out as described on pages 1666—1672 with the one exception that the knee is in extension (fig 1348)

For *suspension of the knee* the stitched pad is placed under the femoral condyles (not the fracture site) so that the distal fragment can sink posteriorly after correction of the shortening

After correction of the shortening by longitudinal traction of 8 to 10 Kg *reduction* is achieved by pressure on the upper end to the tibia while the distal

metaphyseal region of the femur is supported by hand This maneuver abolishes the anterior subluxation and can also reduce a posterior shearing fracture (fig 2355 g, h) In lateral dislocation, as in fig 2360, the condyles are compressed with both hands after correction of the shortening Good position of the fragments can be achieved in most cases (figs 2362, 2363)

First Roentgen Check After reduction new roentgenograms are made exactly from the front and exactly from the side They usually show satisfactory position

Immobilization, second roentgen check, marking and *splitting of the cast* are carried out as described on pp 1675 and 1676

Positioning of the Leg in Bed The leg in the split cast is placed on an oblique frame with a pulley The patient together with the frame is put into the pre-warmed bed The pin is weighted with 6 Kg The uninjured leg is propped against a wooden box (fig 2350)

The *fourth roentgen check*, the *exercises in the bed*, the *closure of the plaster cast*, the *check roentgenograms after three weeks*, the *removal of the first cast*, the *application of the long leg walking cast*, the *seventh roentgen check*, the *exercises*, the *duration of the immobilization*, the *eighth roentgen check* and the *subsequent treatment*, are carried out as described on pages 1676 and 1677

Questions We Should Ask Ourselves in Order to Avoid Failures in the Treatment of Flexion Fractures of Both Condyles with Antecurvation

One should answer the same questions as in bicondylar fractures with recurvation (see p 1677) with the one exception that the limb is fixed in the screw traction apparatus with the knee extended and the suspension placed at the femoral condyles (fig 2348) and not at the fracture site After application of the cast with the knee extended the limb is not placed on a Braun splint but on an oblique splint (fig 2350)

Results of Fresh Fractures of the Upper End of the Tibia

Ender[1] has followed up the 305 fresh fractures of the upper end of the tibia in 303 patients who were treated in our hospital between 1925 and 1948 270 fractures of the tibial spine 30 cup-shaped avulsions from the upper end of the tibia, four avulsions of the tibial tubercle, and two separations of the upper tibial epiphysis are not included with these cases All clinical records and roentgenograms of the 303 patients were studied Of the survivors who could be traced 122 were submitted to a clinical and roentgen examination 2 to 23 years (i e, an average of 8 years) after the accident

Of the 303 patients 248 (81 8%) were male and 55 (18 2%) were female

Age Groups The youngest patient was 19 years old at the time of the accident and the oldest 77 The average age was 46, whereas in fractures of the tibial shaft treated during the same period of time the average age was only 34 years In some statistics, especially of the unicondylar fractures, the average age is much higher

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[1] Ender J Behandlung u Behandlungsergebnisse der Schienbeinkopfbruche Arch orthop Unfall Chir 47 130—145 1955

15 Have I placed the limb on a lower leg splint and exerted traction of 6 Kg at the calcaneus pin (fig 2350 a)?
16 Have I split the plaster cast along the cord at once and throughout its full length?
17 Have I inscribed the plaster cast?
18 Have I raised the lower end of the bed by 30 cm ?
19 Have I suspended the cast at the site of the fracture on the wooden overhead gallows (fig 2350 a)?
20 Have I closed the split cast with a bandage when the swelling has subsided after three or four days?
21 Have I made new roentgenograms after one week?
22 Have I repeated reduction and application of a plaster cast with continuous traction of 6 Kg if the roentgenogram shows displacement?
23 Have I obtained roentgenograms in both planes after application of the new plaster cast?
24 Have I inscribed the new plaster cast?
25 Have I obtained new roentgenograms after three weeks?
26 Have I removed the cast and continuous traction six weeks after the injury?
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33 Have I had the patient carry out the exercises as described on page 1656?
34 Have I removed the walking cast ten weeks after the accident?
35 Have I continued the treatment after removal of the walking cast as for a tilted unicondylar fracture (see questions 19 to 23 on p 1658)?

Treatment of Flexion Fractures of Both Tibial Condyles With Antecurvation
(figs 2355 c, d 2355 g, h, 2360—2363)

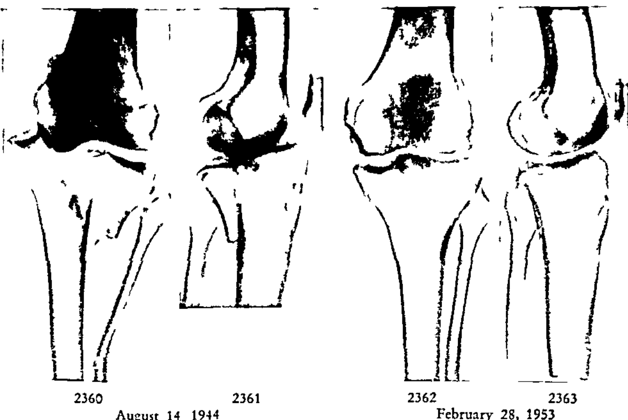
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After correction of the shortening by longitudinal traction of 8 to 10 Kg *reduction* is achieved by pressure on the upper end to the tibia while the distal

Classification 205 (67 2%) of the fractures were unicondylar fractures 184 of the latter were fractures of the lateral, and 21 were fractures of the medial condyle, 51 (16 7%) were fractures of both condyles, and 49 (16 1%) were infracondylar fractures with fracture lines running into the joint

Of the 205 unicondylar fractures, 1 (0 5%) was an open fracture, of the 51 bicondylar fractures, 5 (9 8%) were open fractures, of the 49 infracondylar fractures, 15 (30 6%) were open fractures



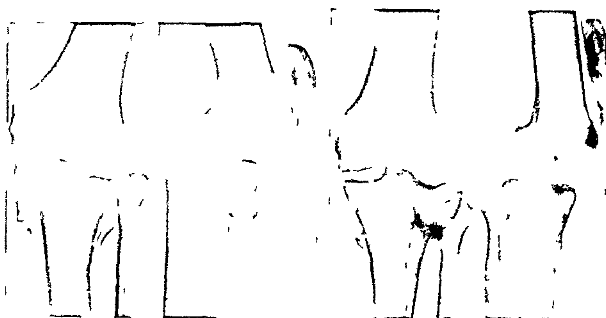
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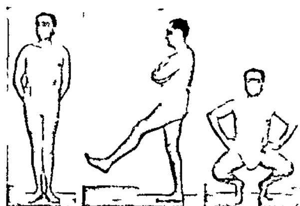
Fig 2360 2361 —Infra and bicondylar flexion fracture and posterior shearing fracture of the upper end of the tibia Fracture of the shaft of the fibula Valgus of 15° Anterior subluxation of the tibia similar to that in fig 2355 g The medial tibial condyle is dislocated medially and cranially The shaft of the tibia is also displaced medially The injury was produced by a barrel which struck a 51 year old truck driver on the anterolateral aspect of his thigh and rolled down his leg while his knee was slightly flexed Reduction under local anesthesia with the knee extended in the screw traction apparatus by calcaneus pin traction of 9 Kg After correction of the shortening anterior pressure was applied on the upper end of the tibia and the condyles were compressed with both hands Long leg walking cast was applied which was split at once and traction of 6 Kg continued for five weeks Then long leg walking cast for another five weeks

Figs 2362 2363 – Check roentgenograms re figs 2360 2361 eight and a half years later Very satisfactory position of the fragments Knee motion 180° to 60° as against 180° to 45° on the uninjured side No arthrosis Asymptomatic

Fatalities Of the 303 patients, 4 (1 3%) died on account of the fracture of the upper end of the tibia viz, (1) a 21 year old girl (open fracture) died from infection on the ninth day in spite of amputation, (2) a 60 year old man (closed fracture) died from pulmonary embolism on the fourteenth day, (3) a 74 year old man (open fracture) died on the third day from fat embolism, (4) a 75 year old man died on the first day He had suffered an open fracture



2356 September 11 1936 2357 2358 September 11 1954



2359 September 11 1954

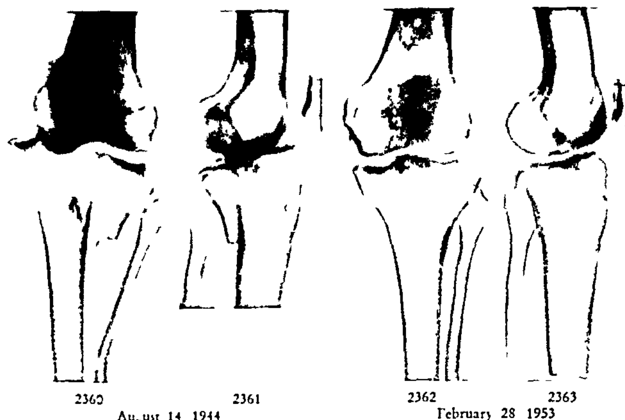
Figs 2356 2357—Infra and bicondylar hyperextension fracture of the upper end of the tibia with avulsion of an anterior infracondylar flexion wedge with a base of 65 mm Displacement of the tibial condyles Dislocation of the head of the fibula Rupture of the patellar ligament avulsion of the tip of the patella Posterior displacement of the distal fragment of the tibia A greater degree of such displacement may tear the tibial artery and cause gangrene of the foot Valgus of 10⁰ + 10⁰ = 20⁰ recurvation (posterior bowing) of 15⁰ + 10⁰ = 25⁰ Sustained by a 21 year old motorcyclist while trying to avoid collision with an automobile when he struck a road railing with his knee Reduction with calcaneus pin traction of 9 Kg in the screw traction apparatus Long leg cast which was split at once and continuous traction of 7 Kg for seven weeks Long leg walking cast for six more weeks Uneventful healing of the wound

Fig 2358—Check roentgenograms re figs 2356 2357 eighteen years later Bony union in good position A slight (10⁰) recurvation was left on purpose to overcome the defect of the patellar ligament A 6 cm cranial displacement of the patella No arthrosis Active motion of knee 150⁰ to 70⁰ passive motion 180⁰ to 70⁰ The patient can now walk long distances without pain During World War II he served as veterinary surgeon performing his duties on horseback

Fig 2359—Photographs re fig 2358 The left leg is slightly weaker The knee can be completely extended when standing When the limb is raised anteriorly extension of the knee is 150⁰ In spite of the strong cranial displacement of the patella extension of the knee is relatively good because the Vastus medialis and lateralis were not injured Knee flexion to 70⁰ The lateral roentgenogram clearly shows the cranially displaced patella

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2360 2361 2362 2363
August 14 1944 February 28 1953

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FIGS 2362 2363 Check roentgenograms re figs 2360 2361 eight and a half years later Very satisfactory position of the fragments Knee motion 180° to 60° as against 180° to 45° on the uninjured side No arthrosis Asymptomatic

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and his leg had been amputated immediately after admission on account of severe comminution

Of the 303 patients, 13 more patients died during treatment from severe concomitant injuries or from diseases

Amputations were performed in three (1 0%) patients Two of the latter have been included in the fatal cases The third amputation was performed in a 46 year old man who sustained an open comminuted infracondylar fracture with rupture of the vessels

Results of the Follow-up Examination The 122 patients re-examined clinically and roentgenologically after 2 to 23 years, were 54 years of age on the average The results were as follows

I	No angulation	80 (65 6%)
	Angulation af 5°—9°	24 (19 7%)
	Valgus of 10°—15°	4 (3 3%)
	Varus of 10°—15°	5 (4 1%)
	Antecurvation of 10°—15°	2 (1 6%)
	Recurvation of 10°—15°	5 (4 1%)
	Recurvation of 16°—20°	2 (1 6%)
II	No lateral instability	80 (65 6%)
	Lateral instability at 170°	30 (28%)
	Drawer sign positive	11 (8 1%)
	Orthopedic splint worn	1 (0 8%)
III	Knee freely mobile or extension limited by not more than 5° and flexion limited by not more than 10°	90 (73 8%)
	Extension limited by 10°—20°	15 (12 3%)
	Extension limited by 30°	2 (1 6%)
	Hyperextension of 10°—20°	5 (4 1%)
	Ankylosis	1 (0 8%)
IV	No arthrosis	87 (71 3%)
	Slight arthrosis (fig 2337)	28 (22 9%)
	Moderate arthrosis	5 (4 1%)
	Severe arthrosis	2 (1 6%)

Gait Of the 122 patients 103 had a normal gait, 14 limped 4 used a stick and one patient had an orthopedic splint

These statistics show that no arthrosis developed even following severe *fractures of the upper end of the tibia (figs 2356—2363) if the fracture had been reduced well and immobilized for a sufficiently long period Arthrotic* changes were surprisingly slight even after angulation deformities (figs 2364—2366) Severe arthrosis was found in cases in which the meniscus was completely removed in other hospitals

Angulation of more than 10° often causes disturbances since it is usually accompanied by lateral instability of the knee The result depends therefore, on the recognition of the primary displacements especially recurvation and varus and on the adequacy of treatment Angulation often occurred in unicondylar fractures with a small marginal fragment and deeply depressed central fragment in those cases which had not been operated on

Open Fractures of the Upper End of the Tibia

Among unicondylar tilted and split fractures of the upper end of the tibia, which generally result from indirect trauma, open fractures are very rare. Of 205 cases we observed but one open fracture. Among the bicondylar fractures, however, open fractures can frequently be seen. Amongst 51 bicondylar fractures we found five and among 49 infracondylar fractures with involvement of the knee joint we observed 15 open fractures.

Origin. Open fractures of the upper end of the tibia are always caused by direct violence. They are most common with motorcyclists who hit a road-railing, a tree, a telegraph pole or another obstacle at great speed with their right knee. Very often they suffer severe associated injuries. The most severely injured patient we have ever seen, sustained, on the right side of his body, open fractures of the upper end of the tibia, the patella, the femoral condyles, and the femoral shaft as well as a closed posterior dislocation of the hip with a sheared-off acetabular roof fracture of the acetabulum and paralysis of the sciatic nerve. Automobile bumpers are very often the cause of open fractures of the upper end of the tibia in pedestrians. When a motorcyclist hits the I-beam of a road railing, usually two wounds result. One may be, for example, at the tip of the patella and the other at the tibial tubercle. The upper edge of the I beam will break off the tip of the patella or tear the patellar ligament. The lower edge of the beam strikes the tibial tubercle, driving it like a wedge between the condyles splitting them asunder. The fibula usually remains intact but upward dislocation of the fibular head occurs (figs. 2356—2359) when the condyles are displaced distally. Sometimes the menisci and the cruciate ligaments are injured. Ehalt[1] described cases of this kind. If the impact occurs a few centimeters higher the patella and the femoral condyles are broken (figs. 2262 a—d).

Treatment. *Treatment of Shock and Wound Excision.* At first the shock is treated as described in Vol. II/p. 1089. To avoid infection wound excision should be performed meticulously under local anesthesia with scalpel and rongeur according to the rules given in Vol. I/pp. 139—174. Dirt and particles of cloth are sometimes driven far into the wound and may be found at the posterior cortex of the tibia or the joint capsule. Soiled and injured menisci are not removed but only smoothed. When the wound has been cleaned the skin, and the skin only, is closed, after insertion of one or more drains. No sutures or ligatures of vessels are buried in the depth of the wound. If the extensor mechanism or cruciate ligaments are torn they must not be sutured. Burying foreign bodies in the depth of these wounds must be avoided. Then penicillin is given locally and systemically. Thanks to thorough excision of the wounds we have experienced infection very rarely, even in the pre-penicillin era.

In a case with extensive loss of skin, Ehalt shortened the tibia for 4 cm to make closure of the skin possible. A very good result was achieved.

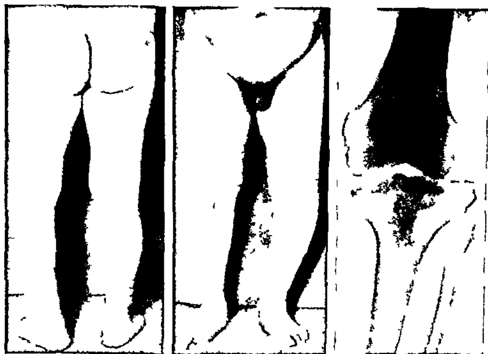
Reduction and immobilization are carried out as in closed fractures as described on pages 1666—1676 with the one difference that slight recurvation is left on purpose in a case of a torn extensor mechanism so that (1) the knee

[1] Ehalt, W.: Monatsschr. Unfallheilk. *44*, 417—427 1937.

can be extended completely when the patient stands and (2) the knee becomes capable of weight bearing without active muscle action (fig 2358)

OLD AND MALUNITED FRACTURES OF THE UPPER END OF THE TIBIA

Open Reduction and Bone-grafting Many fractures of the upper end of the tibia can no longer be reduced by manipulation if the accident occurred *more than three weeks previously* In long-standing tilted fractures, if the



2364 January 5 1926 2365 2366

Figs 2364 2365 —Left leg six years after compression fracture of the medial tibial condyle treated at another hospital See x ray fig 2366 Lower leg in varus position Knee can be moved from 170° to 55° Patient limps and can walk only short distances Unable to carry heavy burdens *Primary treatment wet compresses for three weeks on a Volkmann splint* followed by massage and early passive movements

Fig 2366 —Roentgenogram of the same case Medial condyle at a lower level than the lateral This is a tilt fracture of the medial condyle The lateral condyle is subluxated laterally as in fig 2354 At the present time we would insert a bone wedge medially in such a case

patient's general condition is good it is expedient to expose the fracture site and to insert an adequate bone wedge taken from the iliac bone or the bone bank (figs 2366 a—c)

Osteotomy and Bone grafting If insufficient reduction, short immobilization, early massage or passive movements have led to unsatisfactory position and a loose knee joint as in figures 2364—2370 a one should try to improve the axis of the limb by osteotomy and insertion of a bone wedge This tightens the loose ligaments and the limb becomes not only straight but also stable The amount of regained mobility depends not only on good position of the fragments but also on the age and general condition of the patient and the length of time since the accident

Orthopedic appliances are only rarely necessary, viz, once in our 303 cases

Arthrodesis of the Knee Joint In the severest cases with malunion when the patient has a feeling of the joint giving way with every step, and whose knee goes into a position of recurvation or varus as shown in figures 2367 and 2370 a, resection and arthrodesis is the best treatment if the patient is not too old for operation (figs 2367—2370 c)

At present we use Greifensteiner's[1] method of compression arthrodesis The joint is exposed through a curved incision under general or spinal anesthesia



2366 a February 25 1949 2366 b February 25 1949 2366 c July 11 1953

Fig 2366 a—Three week old fracture of both tibial condyles The lateral condyle has been depressed and a narrow marginal fragment has been split off Sustained by a 43 year old lumberman who fell from a cable car When manipulative reduction failed the fragments were exposed Air entered the joint at operation therefore the meniscus is clearly shown The lateral condyle was levered up by a chisel and a bone graft from the iliac crest was inserted The meniscus was not removed

Fig 2366 b—Check roentgenogram re fig 2366 a The lateral condyle is levered up and supported by the inserted iliac graft The black transverse line is not metal but compact bone of the iliac graft

Fig 2366 c—Check roentgenogram re fig 2366 b four and a half years later Bony union in good position No arthrosis Good functional result Asymptomatic

and in a bloodless field From the femoral and tibial condyles 0 5 to 1 cm of bone are sawed off transversely or slightly oblique so that the limb shows a valgus of 7° to 10° and a flexion of 10° to 15° Both bone ends are held together with two crossed Steinmann pins (fig 2370 b) If roentgenograms in both planes show good position a 1 8 mm stainless steel wire is drilled in the frontal plane through skin and bone at a distance of 3 cm above and below the plane of resection Prior to insertion of the wires the skin should be drawn slightly proximally at the femur and slightly distally at the lower leg to avoid pressure on the skin when the wires are tightened If roentgenograms in both planes show good position of the wires a tension stirrup (fig 2369) is applied and

[1] Greifensteiner Z orthop Chir *83* 406—414 1953



2367 October 5 1928 2368 October 17 1929

Fig 2367 —Roentgenograms of a case of fracture of the medial condyle of the tibia ten months after the accident treated elsewhere by "functional methods Marked varus position with recurvation Joint space markedly diminished on the medial side and increased on the lateral side Knee can be moved from 200° to 35° i e a range of movement of 165° When the knee is straight there is 30° lateral mobility and when flexed the tibia can be moved forward and backward Complete peroneal paralysis walking very unsteady Treated from the first day with massage and passive movements without any fixation

Fig 2368 —Same case one year after resection of the knee Firm bony union with continuity of bone structure At operation the posterior cruciate ligament was seen to have been torn from its femoral attachment the anterior cruciate was stretched but not torn through Walks well At present we would insert a bone wedge antero medially in such a case

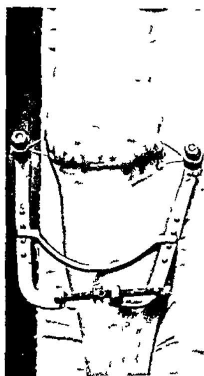
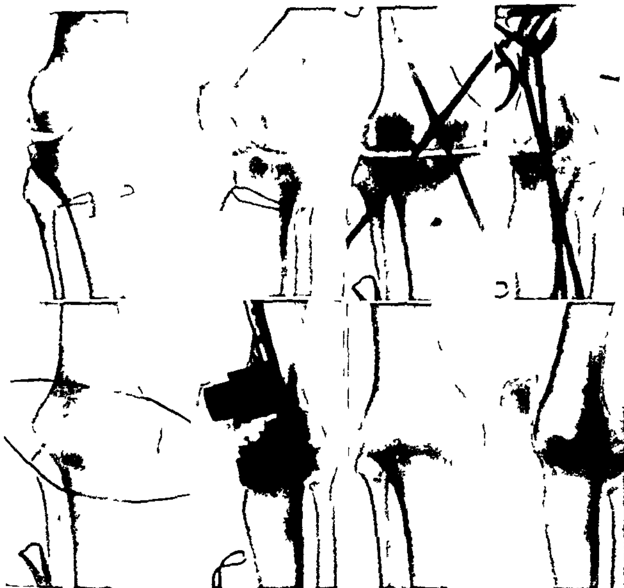


Fig 2369 —Greifensteiner s method of compression arthrodesis of the knee 3 cm away from the planes of resection a stainless steel wire is drilled through the femoral and another through the tibial condyles Both wires are clamped in a tension stirrup The wires can be tightened by turning the *screws of the transverse turn buckle Thus the bone ends are* pressed together and bony union is accelera ed

adequately tightened As soon as the stirrup has been mounted the two Steinmann pins are removed Then the wound is packed and the tourniquet removed If the pack is removed 5 to 10 minutes later there is as a rule only slight hemorrhage Bleeding vessels are then clamped but not ligated The skin is closed and a plaster cylinder applied as shown in figures 2175—2177 The cast

2370 a 2370 b



2370 c November 12 1951 2370 d February 17 1952

FIG 2370 a—Two year old probable bicondylar fracture of the upper end of the tibia treated elsewhere with a wire loop but without reduction of the medial condyle Marked tilting of the medial condyle *Medial joint space very narrow* Varus 15° + 10° = 25° *Sustained by* a 40 year old farmer s wife who fell from a ladder Patient now suffers severe pain and can walk only with a cane

FIG 2370 b—Check roentgenograms re fig 2370 a after resection of both joint ends and insertion of two crossed Steinmann pins The varus has been corrected Knee angle of 170° The patella is not visible as it was pulled up with the soft tissue

FIG 2370 c—The bone ends are compressed by two wires (see fig 2369)

FIG 2370 d—Check roentgenograms re figs 2370 a—c three months later Firm bony union of the fragments in good position Patient can walk without a cane asymptomatic

must be split at once throughout its full length Two weeks later resorption at the cut ends of both bones sets in The screw of the stirrup is then tightened by one turn This is repeated every other day until the middle of the fourth week

Application of the Plaster Cylinder When the cast is removed at the end of the fourth week roentgenograms usually show fair union of the bone ends Now the tension stirrup and the wires can be removed An Unna s paste dressing is applied to the foot and a plaster cylinder to the knee in the manner described on pages 1514—1516 and shown in figures 2175—2177

Duration of Immobilization The plaster cast can be removed eight weeks after operation After this time the knee has generally become firm If not, a new plaster cylinder is applied for another four weeks To avoid edema an Unna s paste dressing is applied from the webs of the toes to mid thigh for another 4 to 8 weeks (see "Verbandlehre , pp 74—86)

Charnley performs compression arthrodesis by driving a pin through the femoral and one through the tibial condyles and using turnbuckles on both sides

Results of Arthrodesis of the Knee

Simon-Weidner[1] has followed up our 40 cases of arthrodesis of the knee performed during the eight years from 1946 to 1953 Our cases were those with severe arthrosis, painful partial ankylosis following gunshot injuries sequelae of purulent and tuberculous joint infection, malunited fractures of the joint-ends and one case of tabes After resection, the first 20 cases were secured against displacement with one or two wire loops placed in frontal planes The second 20 cases were treated according to Greifensteiner s method of compression arthrodesis

Bony union occurred in 39 cases There was no osseous union in the tabetic patient He was given an orthopedic splint In the first series, bony union needed an average of 26 6 weeks, the cases treated after Greifensteiner only took an average of 8 4 weeks The duration of the whole treatment took an average of 34 1 weeks in the first group and 13 6 weeks in the second group

91 SEPARATION OF THE UPPER TIBIAL EPIPHYSIS

Separation of the proximal tibial epiphysis is rare as opposed to distal tibial epiphyseolysis which is common Jorg Bohler[2] has found only four cases among 7600 fractures of the lower leg In the world literature he could find only 26 cases Diagnosis of these cases was definite in only 12 of them

Origin These injuries occurred, as a rule in patients of 14 and 16 years of age, from violent force directed against the upper end of the tibia, namely in the case of figures 2370 a—g, by a vigorous kick against the crest of the tibia in soccer, in another case by the impact of a stack of metal sheets against the lateral side of the knee, and in a third case the patient was caught by a

[1] Simon Weidner Über Kniearthrodesen Wien med Wchnschr 50 991—993 1954

[2] Bohler J Zur Behandlung der traumatischen Epiphysenlosungen am oberen Schienbeinende Chirurg 22 81—83 1951

transmission belt He also suffered a separation of the lower epiphysis of the contralateral femur Gangrene of both lower legs developed because both popliteal arteries were torn

Types of Displacement In general the epiphysis is displaced anteriorly causing recurvation of the tibia Valgus position is rare Comparison roentgenograms should be made of the sound side so that recurvation is not overlooked

Treatment *Reduction* under local anesthesia is achieved without difficulty in most cases In the case of valgus position the lower leg is adducted In the case of recurvation a calcaneus pin is inserted and the lower leg flexed vigorously over the surgeon's forearm placed into the popliteal space as in extension fractures of the upper end of the tibia (see pp 1666—1677)

First Roentgen Check Usually good position is present in both planes

Immobilization In *epiphyseolysis with valgus deformity* application of a long leg cast which is split completely will suffice after reduction Eight to ten days later a long leg walking cast ist applied for another five weeks New roentgenograms must be made after reduction, after application of the first and second plaster cast, and after removal of the cast

In *epiphyseolysis with recur ation* the patient is placed, after reduction, on the screw traction apparatus as for a hyperextension fracture of the upper end of the tibia (see page 1671), the knee being at 150°

Then the *second roentgen check* is made

The *plaster cast* is applied as described on pages 1675 and 1676

The *third roentgen check, placing of the leg on the lower leg splint, marking of the cast, splitting of the cast, positioning of the patient in bed, suspension of the cast closure of the cast* and *fourth roentgen check*, are carried out as described on page 1676

Re-displacement of the epiphysis and recurvation will occur if the cast is applied without calcaneus pin traction, if continuous traction is not exerted in the cast at the calcaneus pin or if the cast is not suspended If the ephiphysis becomes displaced in spite of these measures *transfixion of the tibia* must be performed The first cast is removed and the limb is fixed in the screw traction apparatus If new roentgenograms show good position, a pin is driven or a wire drilled through the upper end of the tibia (fig 2370 f) Then a long leg cast is applied which is not split The pin driven through the upper end of the tibia and fixed in the plaster cast prevents new recurvation of the fragments

Fourth Roentgen Check Four weeks after reduction new roentgenograms are made If they show good position a walking cast is applied

Application of the Long Leg Walking Cast The first plaster cast and the continuous traction are removed and a cast as shown in figures 2175—2177, but including the foot is applied

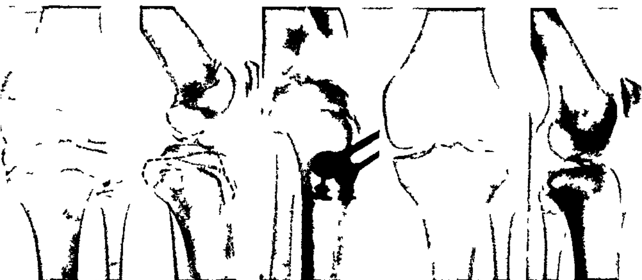
Fifth Roentgen Check After application of the cast new roentgenograms are made

Duration of Immobilization The walking cast is removed after four more weeks

Results Bony union in good position follows good reduction and sufficiently long immobilization The knee joint is freely mobile within 4 to 5 weeks after removal of the cast No subsequent treatment is necessary

Questions We Should Ask Ourselves in Order to Avoid Failures In Separation of the Proximal Tibial Epiphysis

The questions are the same as for treatment of bicondylar fractures of the upper end of the tibia (see pp 1677 and 1678)



2370 e March 20 1949 — 2370 f April 4 1949 — 2370 g March 24 1950

Fig 2370 e—Separation of the proximal tibial epiphysis The epiphysis is slightly laterally and markedly anteriorly displaced Valgus 10° recurvation 25° The normal position of he epiphysis is sketched on the lateral roentgenogram Sustained by a 16 year old boy who while playing soccer sustained a vigorous kick against the anterior aspect of the lower leg Reduction under general anesthesia by powerful flexion of the lower leg over the surgeon s forearm placed in the popliteal space Plaster cast with the knee at an angle of 150° Because the check roentgenogram showed re displacement a new plaster cast was applied at 90°

Fig 2370 f—Check roentgenogram re fig 2370 e after reduction and immobilization with forward traction by means of a Steinmann pin

Fig 2370 g—Check roentgenograms re fig 2370 e after one year Bony union in good position The epiphyseal line is closed Full range of active motion Asymptomatic Figs 2370 e—g are taken from a paper by Jorg Bohler

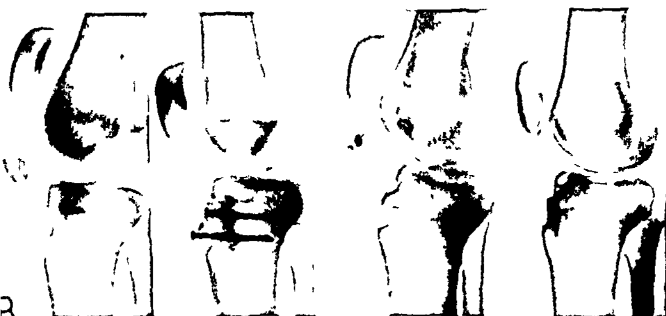
92 EPIPHYSIOLYSIS AND AVULSION OF THE TIBIAL TUBERCLE

Epiphysiolysis of the tibial tubercle is as rare as epiphysiolysis of the proximal end of the tibia Will[1] has collected only 37 cases including avulsion of the tibial tubercle in adults Among these cases there was only one girl — of 14 Most patients were 15 to 16 years of age Some authors report larger numbers by including Osgood Schlatter s disease Schonbauer collected seven avulsions and only two cases of epiphysiolysis of the tibial tubercle out of 620 injuries

1 Will Die Frakturen der Tub tibiae Zentralbl Chir 77 1793—1798 1952

of the extensor mechanism of the knee The two cases of epiphysiolysis showed no perceptible displacement (see p 1512) In 1955 we observed our first case of epiphysiolysis of the tibial tubercle with marked displacement (fig 2370 h)

Among the seven cases of avulsion of the tibial tubercle only two showed marked displacement (fig 2370 k) In this case there was a transverse gap in



2370 h February 6 1955 | 2370 i March 4 1955 | 2370 j November 17 1943 | 2370 k May 22 1948

Fig 2370 h Epiphyseal separation of the tibial tubercle which is broken into two pieces of a size of 20×30 mm each The anterior piece of bone represents the tip and the posterior triangular piece the base of the tibial tubercle The patella lies 50 mm cranial to the upper anterior edge of the tibia Sustained by a 15 year old apprentice who tried to jump on a street car caught his right foot on a crack in the pavement and fell on his right knee

Fig 2370 i Check roentgenogram re fig 2370 h Both fragments have been reduced and fixed with screws The torn extensor apparatus has been sutured The tip of the patella is only 22 mm cranial to the tibial edge

Fig 2370 j—Avulsion of the tibial tubercle producing a 25×10 mm gap Rupture of the patellar ligament with a 20 mm superficial comminuted bone chip lying at the level of the joint space Tip of patella 35 mm cranial to upper anterior tibial edge Sustained by a 40 year old mason who fell 3 M into a cellar on his right knee The large fragment was pressed into its proper place with a bone elevator and sutured with the patellar ligament to the tibial periosteum

Fig 2370 k—Check roentgenogram re fig 2370 j four and a half years later The patella lies 20 mm cranial to the tibial edge Distal to the patella there are two small bone shadows of 5 mm diameter Normal usefulness of the limb

the bone and an avulsion of a superficial comminuted shell of bone which was markedly dislocated cranially In the cases of epiphysiolysis and in the cases of avulsion of the tibial tubercle with great displacement, the extensor mechanism was torn for 4 to 5 cm on both sides

Origin Most cases of epiphysiolysis which have become known originated from a leap over a wooden horse in physical training or over another gymnastic apparatus in which the person made a bad landing with a bent knee Our

patient sustained this injury when he jumped on a streetcar in motion and slipped In these jumps with a bad landing the knee gives way unexpectedly while the quadriceps muscle is still under maximum tension This causes the tibial tubercle to tear out

Diagnosis Patients with severe displacement cannot actively extend their knee Swelling sets in rapidly In some cases the projecting piece of bone is visible immediately after the injury As in patellar fractures, the gap in the extensor mechanism can be palpated In cases with slight displacement there is but slight swelling and localized tenderness The roentgenogram shows the degree of injury and the kind and degree of displacement

Treatment In avulsion with slight displacement application of an Unna s paste dressing and a plaster cylinder for six weeks (see pp 1515—1517 and *figs 2175—2177) will suffice*



2371 February 17 1934 2372

Fig 2371 —Comparison roentgenogram re fig 2372 of the sound side
Fig 2372 —Dislocation of the head of the fibula Sustained by slipping on a hill

In avulsion with separation of the fragments the fragments are exposed through a curved incision In epiphysiolysis the fragments are apposed with single pronged bone hooks and secured with screws (fig 2370 i) In addition the extensor mechanism is sutured In adults the separated piece of bone is often very thin and comminuted so that it cannot be held by a screw It is then sutured to the tibial periosteum (fig *2370 m*) *After operation the* limb is supported on a Braun splint or a pillow If the swelling has subsided after 8 to 10 days an Unna s paste boot and a plaster cylinder are applied, and *removed six weeks after operation*

93 DISLOCATION OF THE HEAD OF THE FIBULA

Dislocation of *the fibular head is often observed together with fracture* of the upper end of the tibia (fig 2356), isolated dislocation is, however, very rare (fig 2372)

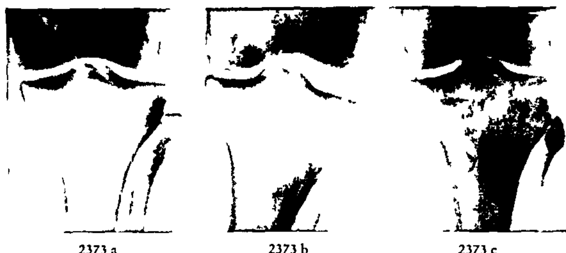
Origin This dislocation is caused by an incoordinated turn

Diagnosis The fibular head projects lateroposteriorly (fig 2372) and is tender to pressure

Treatment Under local anesthesia the fibular head can easily be pressed into its normal place The reduced position can be retained permanently in a plaster cylinder (figs 2175—2177) which is applied for four weeks

94 AVULSION FRACTURE OF THE HEAD OF THE FIBULA

Origin Avulsion fracture of the fibular head is rare It results from indirect violence by a sudden vigorous adduction of the thigh when the lower leg is fixed forcing the knee into varus *We observed a case in which a skier s* right foot was caught in a hole He fell on his left shoulder while his right knee was forced outward This fracture belongs to the injuries of the lateral collateral ligament (see p 1577)



2373 a 2373 b 2373 c

Fig 2373 a Avulsion of the tip of the fibular head and of the tibial spine Produced by the impact of an automobile on the anteromedial side of the knee

Fig 2373 —Comparison roentgenogram of fig 2373 a in forced adduction The lateral joint space can be opened to 15 mm

Fig 2373 c —Same case after bone suture The tip of the fibular head is again in its proper place and the lateral joint space is normal

If an impact hits the medial side of the extended knee with the lower leg fixed the medial condyle of the femur (Vol II/figs 2027, 2026) or the tibia (fig 2324) will be sheared off depending whether the impact affected the region above or below the knee joint

Type of Fracture and Displacement Only the uppermost part of the fibular head becomes avulsed as shown in fig 2373 Depending on the degree of the force the avulsed piece will be more or less displaced proximally In one case the separation was 3 5 cm and the avulsed fragment was on the level of the joint space This is only possible if the lateral capsule and soft parts have been extensively torn Partial or complete *paralysis of the peroneal nerve* often results from overstretching or rupture of this nerve If the biceps muscle has drawn the avulsed piece of bone as high up as the femoral condyle, the fragment may become included in the joint together with the torn capsule In one case we observed avulsion of the fibular head associated with rupture through the middle of the lateral collateral ligament

Diagnosis On examination the mobility of the toes and the ankle joint must be checked in order not to overlook paralysis of the peroneal nerve. The higher the avulsed piece is drawn up, the bigger are swelling and hematoma, and the more the lower leg can be adducted. As a rule, walking is impossible at first. *At a later attempt to walk, the knee bends laterally.* The avulsed piece can be palpated as a movable hard body at the lateral side of the knee joint. The degree of the injury can only be judged from a roentgenogram made in forced adduction of the lower leg with the site of injury under local anesthesia.

Treatment Open operation is the only treatment, because there is no other means to bring down the displaced piece of bone or to retain it in proper position. If the fragment of bone with the attached collateral ligament is not fixed, the joint will remain unstable. Under local or general anesthesia the site of the fracture is exposed through an incision running downwards and forwards. The incision should be placed sufficiently far in front to avoid injury to the peroneal nerve. The fragment drawn up by the biceps is pulled down by a strong bone hook. If this is difficult in long-standing cases the knee should be flexed. The fragment is fastened to the shaft of the fibula by means of two stainless metal wires perforating the bones (fig. 2373 c). If an attempt is made to fix the head by periosteal sutures only, these tear out and displacement recurs.

In paralysis, the peroneal nerve is exposed to see whether it is merely stretched or torn. If it is severed it must be sutured.

Immobilization After closure of the wound a plaster cylinder (figs. 2175—2177) is applied and split immediately. One week later the stitches are removed. An Unna's paste dressing is then applied to the foot and ankle and a new plaster cylinder in which the patient can start walking. In paralysis of the peroneal nerve the foot must be included in the cast.

Duration of Immobilization The plaster cylinder is removed six weeks after the injury.

The *exercises* and further treatment are carried out as described on page 1516.

Results of Treatment After a few weeks the knee joint regains a full range of motion. If the wire suture has been applied well the knee will be laterally stable. If the peroneal nerve is only stretched, function is recovered in a few weeks or months. If it is torn, permanent paralysis will sometimes remain in spite of the suture.

95 CLOSED FRACTURES OF THE TIBIAL AND FIBULAR SHAFTS

Origin of the Fractures of the Shafts of the Tibia and Fibula These fractures result from indirect rather than from direct violence. (1) They occur from *indirect* force, as in skiing, more often as external (fig. 2373 d, e) than as internal torsion fractures (fig. 2373 f) when the patient's weight is on one foot while the body is twisted either away from (external torsion fracture) or toward the fixed foot (internal torsion fracture). (2) They occur from *direct*

force e g , by the impact of a heavy object (fig 2373 i) or when the patient is hit by a fellow footballer (fig 2373 r) or is run over

Types of Fracture Indirect violence causes long torsion fractures (fig 2373 d), short torsion fractures (fig 2373 e), or so called "half torsion fractures (fig 2373 g) of the tibia The fracture surfaces and fracture clefts are long and screw shaped (spiral)

In the more frequent outward torsion fractures the tip of the proximal fragment lies at the medial side of the posterior surface of the tibia, in the less frequent inward torsion fractures this prong lies at the lateral side of the posterior surface of the tibia

The "half' torsion fracture is a special type of fracture, in which the terminal fracture' does not lie in the posterior surface of the tibia, but lies partly in the medial or lateral surface of the tibia (figs 2373 g, 2379—2382 and 2464—2469) This fracture is of particular importance since its fragments sometimes become displaced by the full width of the shaft in longitudinal traction If these fragments are not reduced callus formation will be delayed

Site of the Fracture Most torsion fractures of the tibia are located at the junction of the middle and lower thirds while the fibula breaks in its upper third (figs 2373 d—g) The fibula may also break in the middle or lower third Most bending fractures occur in the middle third (figs 2373 i, 2413, 2458—2463)

The *displacement* are manifold, they depend on acting force, muscle pull, subsequent positioning, and treatment In about one third of all fractures of the shafts of the tibia and fibula there is no primary displacement in about a quarter of these cases it amounts to the width of the cortex of the shaft (fig 2373 f) Only 2% of the torsion fractures and 10% of the bending fractures are displaced by as much as a full shaft s width (fig 2373 h)

Most closed fractures of the tibia and fibula show no displacement or but very little primary displacement, for instance, 40% of these fractures had no shortening, 39% had a shortening of 1—5 mm , 15% 6—10 mm , 3% 11—15 mm , 1% 16—20 mm , and only 1% more than 20 mm

Complete (fig 2373 p) or incomplete (fig 2373 m) "torsion wedges (broken off wedge fragments in torsion fractures) were observed in 24% of all torsion fractures Complete (fig 2373 s) or incomplete (fig 2373 r) bending wedges (broken off wedge fragments in flexion fractures sometimes called butterfly fragments) were observed in 32% of all flexion fractures

Ender Krotschek and Jahna [1] have published exact data about the types of fracture and the relative frequency of torsion and bending fractures the frequently and size of different displacements, and the associated injuries of our 1130 closed fractures of the shafts of the tibia and fibula

Associated Injuries Pressure upon the tibial artery (fig 2378 f) *or rupture* of this artery is the severest complication Fortunately, it occurs very seldom I have observed it but once in our cases

Paralysis of the peroneal nerve is observed in some cases of associated dislocation of the fibular head

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[1] Ender Krotschek and Jahna Beihefte z Monatschr f Unfallheilk 1956

Diagnosis On examination the mobility of the toes and the ankle joint must be checked in order not to overlook paralysis of the peroneal nerve The higher the avulsed piece is drawn up, the bigger are swelling and hematoma, and the more the lower leg can be adducted As a rule, walking is impossible at first At a later attempt to walk, the knee bends laterally The avulsed piece can be palpated as a movable hard body at the lateral side of the knee joint The degree of the injury can only be judged from a roentgenogram made in forced adduction of the lower leg with the site of injury under local anesthesia

Treatment Open operation is the only treatment, because there is no other means to bring down the displaced piece of bone or to retain it in proper position If the fragment of bone with the attached collateral ligament is not fixed, the joint will remain unstable Under local or general anesthesia the site of the fracture is exposed through an incision running downwards and forwards The incision should be placed sufficiently far in front to avoid injury to the peroneal nerve The fragment drawn up by the biceps is pulled down by a strong bone hook If this is difficult in long standing cases the knee should be flexed The fragment is fastened to the shaft of the fibula by means of two stainless metal wires perforating the bones (fig 2373 c) If an attempt is made to fix the head by periosteal sutures only, these tear out and displacement recurs

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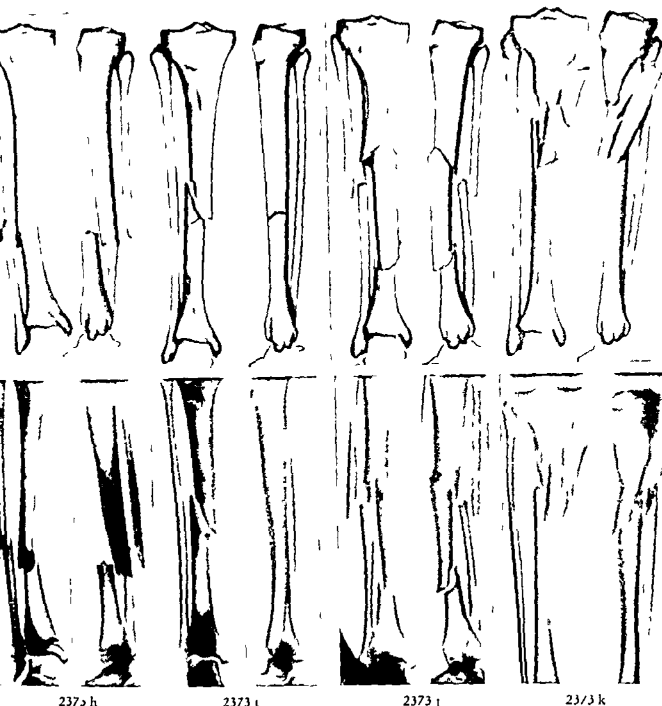
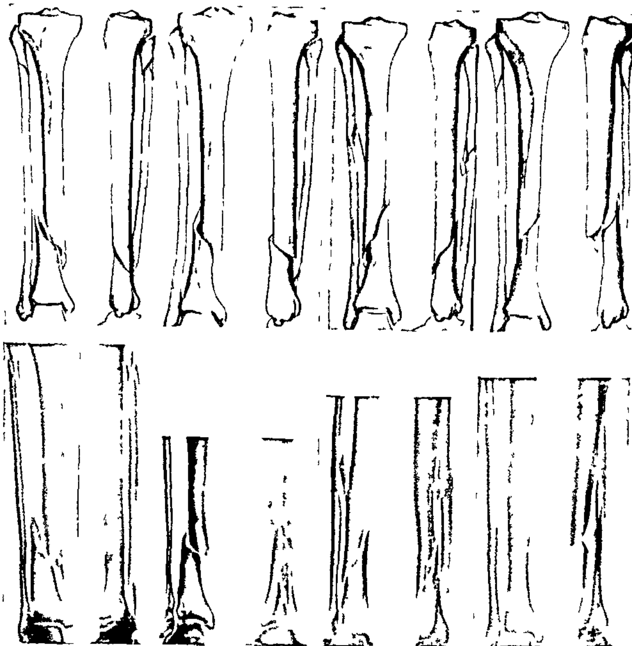


Fig 2373 h —Transverse bending fracture of the tibia and fibula at the junction of the middle and lower thirds in a 14 year old boy who hit a tree when skiing The fracture surfaces are at a right angle to the tibial shaft Anterior displacement of the distal fragment of the tibia by the full width of its shaft of the fibula by double the width of its shaft Shortening of 15 mm

Fig 2373 i —Oblique bending fracture through the middle of the tibia in a 26 year old man who was kicked by a horse The fracture cleft runs obliquely A lateral incomplete flexion wedge has been broken off of the distal fragment

Fig 2373 j —Double fracture of the tibia with a 15 cm long middle fragment and transverse fracture through the mid shaft of the fibula in a 45 year old man who was knocked down by a truck

Fig 2373 k —Comminuted fracture of the upper third of the tibia and linear fracture below the fibular head in a 35 year old man who was knocked down by an automobile There is longitudinal and lateral separation between the proximal main fragment and the middle fragments of the tibia There is shortening without lateral separation between the distal main fragment and the middle fragments



2373 d 2373 e 2373 f 2373 g

Fig 2373 d—Long *outward torsion fracture* of the lower third of the tibia and the upper third of the fibula sustained by a 31 year old surgeon while skiing The spiral fracture cleft runs from the *medial* surface over *the anterior crest to the lateral surface* The *terminal* fracture lies in the posterior surface The tip of the proximal fragment lies *medially*

Fig 2373 e—Short *outward torsion fracture at the junction* of the middle and lower thirds of the tibia and of the lateral malleolus in a 39 year old man sustained by a fall The fracture cleft passes in a relatively flat curve from the *medial* surface of the tibia over the anterior crest to the lateral surface The terminal fracture lies in the posterior surface The tip of the proximal fragment lies *medially*

Fig 2373 f—Long *inward torsion fracture* at the junction of the middle and lower thirds of the tibia and above the middle of the fibula with a large torsion wedge Sustained by a 40 year old woman while skiing The fracture cleft has the shape of a long screw and passes from the *lateral* surface of the tibia over the anterior crest to the medial surface The terminal fracture lies in the posterior surface The tip of the proximal fragment lies *laterally*

Fig 2373 g—*Half inward torsion fracture at the junction of the middle and lower thirds* of the tibia and of the upper third of the fibula in a 39 year old man who fell when skiing *Posterior* displacement of the distal fragment a full shaft s width The terminal fracture lies partly in the posterior and partly in the lateral surface of the tibia In the medial view the fracture surface of the proximal fragment is visible in the lateral view that of the distal fragment is visible In the anteroposterior or the posteroanterior view the [illegible]

so no fracture surfaces are visible Figs 2373 d—[illegible] Ender et [illegible]

Avoidance of Complications Following Fractures of the Shafts of the Tibia and Fibula Death from embolism or pneumonia, and gangrene following rupture of an artery, cannot be avoided If the vessels are only compressed, gangrene can be avoided by early reduction (see case history of fig 2378 f, g) Non union can be avoided if excessive traction weights are avoided and operative treatment is performed in exceptional cases only Perceptible shortening, angulation or rotation can always be avoided by adequate reduction and proper immobilization Limitation of motion and muscle atrophy will be but slight if adequate circulation is ensured by elevating the injured leg and



2373 q 2373 r 2373 s 2373 t

FIG 2373 q —Oblique bending fracture through the middle third of the tibia without a bending wedge The fibula shows a flexion fracture with a lateral wedge in continuation of the oblique fracture cleft of the tibia Sustained by a 29 year old man in an automobile collision

FIG 2373 r —Oblique bending fracture of the tibia with an incomplete bending wedge at the distal fragment The fibula has been fractured at the same level Sustained by a 19 year old boy who was hit on the lateral side of his lower leg by a fellow footballer

FIG 2373 s —Bending fracture of the tibia with a complete lateral bending wedge double fracture of the fibula at the same level Sustained by a 47 year old carpenter by the impact of an 8 cm beam on the lateral side of the lower leg The length of the fibular fragment corresponds to the width of the beam The fibular fragment lies in continuation with the base of the tibial bending wedge

FIG 2373 t —Bending fracture of the tibia with a large dorsal bending wedge which has lost all contact with the tibia A corresponding piece has been avulsed from the fibula The grossly displaced bending wedge is difficult to see in the anteroposterior roentgenogram as its shadow coincides with that of the tibia Sustained by a 29 year old motorcyclist who was knocked down by a truck

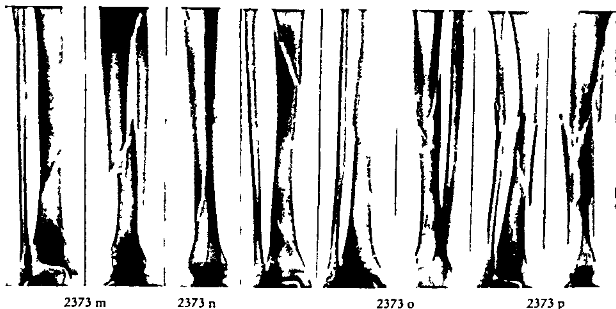
avoiding constricting bandages Arthrosis of the ankle and subtalar joints will develop in some cases in spite of adequate treatment

The importance of the fractures of the shafts of tibia and fibula in national economy is best understood from Kaspar s[1] statistics to which I referred in

[1] Kaspar Verh d Dtsch Ges f Chir 69 Tag Langenbecks Arch u Dtsch Z Chir 273 93 1952

Injuries of the Ankle Joint Associated fractures of the malleoli and fissured fractures running to the lower articular surface of the tibia have been encountered in 14% of the torsion fractures and in 7% of the flexion fractures

Diagnosis of the fractures of the shafts of the tibia and fibula is simple in the presence of displacement as they show the definite signs of a fracture, namely, abnormal shape (angulation, rotation and shortening), abnormal mobility and crepitation In fractures without displacement there is, as a rule pain, swelling and inability to bear weight The roentgenogram reveals the details



2373 m 2373 n 2373 o 2373 p

FIG 2373 m – Long inward torsion fracture of the tibia with the continuation of the fracture cleft in the distal fragment in a 34 year old woman who fell when skiing

FIG 2373 n —Double outward torsion fracture of the tibia in a 16 year old boy who fell when skiing The spiral fracture line runs from the proximal to the distal third of the tibia No displacement of the fragments

FIG 2373 o —Long torsion fracture of the tibia with a medial and posterior torsion wedge which is broken in two No significant displacement of the fragments Sustained by a 19 year old boy who fell 3 50 m from a tree

FIG 2373 p Torsion fracture of the tibia and fibula with two complete torsion wedges avulsed from the tibia One torsion wedge lies anteromedially the other one posteriorly at the same level Displacement a third of the width of the shaft Sustained by a 16 year old girl who fell when skiing

Complications Following Fractures of the Shafts of the Tibia and Fibula Death may be caused by embolism or pneumonia Gangrene resulting from rupture of a vessel or from a too tight bandage or cast is exceptional

In general infection results from operative treatment Non-union is observed in no other fractures of the shafts so often as in those of the lower leg bones Shortening, angulation rotation limitation of mobility of the ankle joints, muscle atrophy and swelling are often seen Arthrosis of the talocrural and subtalar joints frequently develops in subsequent years, arthrosis of the knee joint is rare

toes to the knee, and by an elastic bandage round the knee (see "Verbandlehre," pp 74—86) During the entire treatment the reciprocal effect of pain and impeded blood circulation becomes evident Impeded circulation especially when due to constricting bandages causes pain Pain in turn causes spasm of the vessels and thereby impedes circulation Whether the functional result will be impaired transiently or permanently depends on the degree of circulatory disturbance

Besides carrying out all these measures to provide for optimal circulatory conditions, the most important aim of fracture treatment is to produce an adequate shortening, as every fracture is followed by devitalization and absorption of the fracture ends of from 0 5 to 3 mm because of rupture of vessels and resulting impaired blood circulation An opportunity must therefore be given the fragments to approach each other Thus, in all fractures of the tibia and fibula, we should strive for a shortening of from 1—5 mm , and under no circumstances for lengthening This statement may cause some surprise, because up to now the aim has always been to eliminate any shortening The amount of shortening to strive for is usually 5 mm or less

The lengthening of a bone by separation of the fragments (dislocatio ad longitudinem cum elongatione aut distractione) is the most dangerous of all displacements as all the severe complications described in Vol I/pp 25—27 may follow (fig 2518)

Methods of Treatment in Fractures of the Shafts of the Tibia and Fibula The following methods of treatment exist 1 Splinting, 2 Plaster cast, 3 Continuous traction alone, 4 Continuous traction followed by a long leg walking cast, 5 Operative procedures without exposure of the fracture site (transfixing pins), 6 Operative procedures with indirect exposure of the fracture site, namely, (a) closed medullary wiring, (b) closed medullary nailing, 7 Operative procedures with direct exposure of the fracture site, namely, (a) open medullary wiring (b) open medullary nailing, (c) the loose wire loop and loose wire suture, (d) firm osteosynthesis with wire or a metal band (Putti, Parham), (e) the firm transverse or longitudinal wire suture, (f) screw fixation, (g) plating

In all these procedures care must be taken that the circulation of blood is not impeded by constricting bandages

1 *Splinting* Fractures without displacement may be placed on splints, e g, a gutter splint, until the swelling has subsided With this the swelling will subside much more slowly than in a properly applied traction bandage After the swelling has subsided, a long leg walking cast is applied

2 *Plaster cast alone* Fractures without displacement or with but slight displacement may be treated with a long leg plaster cast which must be split immediately throughout its full length We have treated a fourth of our closed fractures of the shafts of the tibia and fibula with a plaster cast alone When the swelling has subsided a closed full leg walking cast is applied

3 We have never used *traction alone* for the entire period of treatment

4 *Traction followed by a long leg walking cast* We consider this kind of treatment the best for all fractures of the shafts of the tibia and fibula and therefore use this method in most cases

my lecture[1] on tibio-fibular fractures in 1953 Within 3½ years Kaspar operated on 98 fractures of the tibia and fibula for delayed callus formation or non-union In a spot check in the beginning of 1952, when he had 76 patients in his accident clinic Hohenaschau for after-treatment, 23 of these, i e, 30 per cent, were cases of severe sequelae after fractures of the shafts of the tibia and fibula Several of these patients had been under treatment for more than three years Rohlederer,[2] who surveyed 168 cases of fractures of the shafts of the tibia and fibula, reports similar unfavorable results According to Kaspar s and Rohlederer s publication the use of excessive weights for continuous traction and infection following operative treatment are the main causes for severe permanent complications such as non union, dystrophy, deformity, or draining sinuses The economic importance of the fractures of the shafts of the tibia and fibula is well understood since in some places such complications amount to one third of not only the fracture cases but of all accident cases

GENERAL CONSIDERATION ON THE TREATMENT OF FRACTURES OF THE SHAFTS OF TIBIA AND FIBULA

As in all bone fractures the fundamental principles of fracture treatment must be observed, also in those of the shafts of tibia and fibula, namely *Reduction, Immobilization,* and *Exercises* (see Vol I/p 15)

The fate of the fractured extremity depends primarily on sufficient circulation of blood *Reduction* of the fragments not only corrects the existing *deformity* but also in the case of gross displacement, releases the pressure of the displaced fragments on the vessels and restores the blood flow, as shown, e g, in figures 2378 f, g

Immobilization Circulation should be carefully observed during immobilization This is best achieved by leaving the lower leg free from any bandage *during the first week immobilizing it by a calcaneus pin or wire traction and* elevation With proper application of continuous traction pain will disappear at once or after 1—2 days, with it will disappear the cramps of the vessels caused by pain Excessive weights should not be used during continuous traction as they would produce cramps of the vessels with consequent impairment of blood circulation

If a plaster cast is applied on the first day it must be split throughout its full length and down to the last thread immediately i e before the patient leaves the cast room The toes should be left uncovered in all bandages for easy observation of the circulatory conditions

Immobilization should be immediately followed by adequate *exercise which must cause no pain* The toes should be actively moved through their full range from the first day on This furthers the circulation of blood When a long leg cast has been applied walking is the best exercise Avoidance of pain must be stressed Swelling following removal of the cast can be best avoided by applying an Unna s paste dressing extending from the webs of the

1 Bohler L Verh d Dtsch Ges f Chir 70 Tag Langenbecks Arch u Dtsch Z Chir *276* 192 1953

2 Rohlederer Verhandlungen d Deutsch Orthop Gesellschaft 41 Kongreß Beilageheft d Ztschr f Orthop *84* 168—175 1953

leg plaster cast which is split immediately down to the last thread When the swelling has subsided a full leg walking cast is applied

Treatment of the Closed Fractures of the Shafts of Tibia and Fibula with Splints and Subsequent Full Leg Walking Plaster

If a general practitioner wants to treat a closed fracture of the tibial and fibular shafts at home or if there is no hospital bed available, fractures showing little or no displacement (i e, more than 50% of the cases) may at first be treated with splints until the swelling has subsided The simplest and most suitable splint is Volkmann's iron boot (gutter splint) For some time we had tried Cramer wire splints but they proved unsuccessful

For treatment of a fracture of the tibial and fibular shafts with a sheet iron boot the following materials are required

1 A Volkmann gutter splint, a sheet iron boot, with a hole at the heel and a sufficiently big T-bar attached to the sole to avoid rotation of the splint,
2 Three rolls of cellulose or sheet wadding 15 × 100 cm
3 A gauze or cotton bandage, 15 cm × 10 m

Clinical examination, local anesthesia of the fracture sites and *roentgenograms* are carried out as described on pages 1705 and 1706

Padding of the Sheet Iron Boot Two rolls of cellulose are evenly laid out on the sheet iron boot and fixed with a bandage to the sole

Placing the Lower Leg in the Gutter Splint The leg is placed in the boot, covered with the third roll of cellulose from the webs of the toes up to the mid thigh and fixed with the bandage

Observation of Blood Circulation and Exercises The toes must remain uncovered so that they can readily be observed for their circulatory condition In addition, the patient is requested to move his toes actively through a maximum range

Application of the Full Leg Walking Plaster When the swelling of the lower leg has disappeared 10 to 14 days later, a full leg walking cast is applied according to the rules given on pages 1724, 1725 In fractures without displacement the cast may be removed eight weeks later An Unna's paste boot and an elastic bandage round the knee should follow (see p 1733)

Questions We Should Ask Ourselves in Order to Avoid Failures in the Splint Treatment of Closed Fractures of the Snafts of the Tibia and Fibula

1 Have I treated with splints solely fractures without primary displacement?
2 Have I used a Volkmann splint with a sufficiently big hole for the heel and with a T bar for the foot?
3 Have I sufficiently padded the sheet iron boot (gutter splint)?
4 Have I left the toes uncovered by the bandage?
5 Have I applied a full leg walking cast 10 to 14 days later?

Treatment of Closed Fractures of the Shaft of the Tibia and Fibula by a Bed Plaster Cast and Subsequent Long Leg Walking Cast

Closed fractures of the shafts of tibia and fibula without or with but slight displacement, may be treated in plaster from the first day on

5—7 In spite of all antibiotics there is the danger of infection associated with the different *operative procedures* Moreover, callus formation is delayed in all operative procedures

From 1916 to 1928 I treated[1] about 1000 fractures of the shafts of the tibia and fibula by continuous traction with either the Steinmann pin or, later, with Schmerz s traction clamp, the leg being placed on a lower leg splint (*figs 2374, 2375*) When we saw how severe transverse or comminuted fractures, especially near the knee or ankle joint, could easily and completely be reduced in the screw traction apparatus whereas this was rather difficult in some cases with continuous traction, we began reducing most fractures of the tibia and fibula in the screw traction apparatus and applied a lower leg plaster cast which was split immediately throughout its full length The leg was placed on a lower leg splint and continuous pin traction was exerted with 3—6 Kg Reduction was easy in most cases but later on, when the swelling had subsided, new angulation and lateral displacement occurred in many cases These displacements could not be corrected with plaster casts In 1929 we placed the fractured leg on Cramer wire splints for one week, carried out reduction in the screw traction apparatus when the swelling had subsided and immobilized the fragments with two transfixing pins in a plaster cast (transfixation) The technique of this treatment is relatively difficult and time-consuming Moreover, different complications may follow If traction had been excessive, callus formation was delayed If the pins had not been properly driven in and incorporated in the plaster, infection developed at the pin sites For these reasons we stopped using the cast with the transfixing pins after 1933

In 1941 when I was away I gave my assistants permission to use medullary nailing I was mainly influenced by Kuntscher s statement that the medullary nail furthered callus formation I hoped that the many complications following excessive traction could thereby be avoided When my assistants sent enthusiastic letters about this new kind oft treatment I recommended it in the 9th—11th German Edition of my book on Fracture Treatment When I came home in 1943 and re examined all cases treated by medullary nailing (65 closed and 45 open fractures of the tibia and fibula) the results proved unfavorable as against the former methods We therefore gave up medullary nailing of the lower leg fractures in 1943 Krosl re examined the nailed cases after a follow-up period of 8 to 10 years

At present we again treat most fractures of the shafts of the tibia and fibula by continuous traction with the calcaneus pin on a lower leg splint (fig 2374) in the same way as in 1917 (fig 2378 c) In the case of severe displacement the fragments are first reduced manually or in the screw traction apparatus

If the patients urgently want to return home soon we place the fractured leg if there is no or but slight displacement in an iron boot or apply a full

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[1] Bohler L Über die Einheitsbehandlung der Unterschenkelbruche Munchen med Wchnschr 68 1918

Krosl W Beiheft zur Mschr fur Unfalheilkunde Revisione critica e limitazione dell inchiodamento endomidollare Archivo Putti 5 568—584 1954

Treatment of Shock. If the patient is cold or in shock due to associated severe injuries, he is warmed up by blankets and a radiant heat cradle. Treatment of shock has been described in Vol. II/p. 1089.

Physical Examination. As soon as the patient has recovered from shock the physical examination is performed. After ascertaining the patient's general condition and the external shape and color of the injured leg, one should test the dorsalis pedis and posterior tibial pulses. The pulses must be tested especially if the foot is blue or pale and cold. Should, in exceptional cases, gangrene of the foot or lower leg develop following rupture or compression of the tibial arteries, one avoids trouble in indemnity cases if absence of tibial pulses of the injured side only have been recorded in the case history at the first examination. Changes of color and skin temperature due to impeded circulation should also be noted (see case history of fig. 2378 f, g). In all cases of gangrene which have become known to me description of the pulses, the color and the skin temperature of the foot was missing. It was therefore difficult to determine whether the gangrene was the result of a primary injury to the vessels or of a constricting bandage. In fractures of the upper third with as severe a displacement as shown in figures 2378 f, g primary rupture of the vessels can be assumed.

The patellar tendon reflex on the sound side is tested and the reactions of the pupils to light and convergence are examined. This must never be omitted in patients who are strinkingly insensitive (tabes dorsalis). Mobility of toes and ankle joints and sensibility of both feet are also examined. All findings should be written down.

For *reduction* and *treatment* of fracture of the shafts of the tibia and fibula by continuous traction, the following are required:—

1. Local anesthesia (see Vol. I/p. 118 and fig. 152),
2. Satisfactory anteroposterior and lateral roentgenograms (figs. 2373 d—p),
3. A bed with firm support (boards between hair and spring mattresses, Vol. I/figs. 99, 100, 118, figs. 2374, 2375),
4. A well-bandaged lower leg splint (figs. 111, 2374, 2375),
5. A supplementary U-support for the lower leg splint (figs. 109 b, 2374, 2375),
6. A radiant heat cradle,
7. In cold weather a hot water bottle (Vol. I/fig. 157, Vol. II/fig. 1604 d),
8. A roll of cellulose or foam rubber 20 cm. long and 5 to 6 cm. in diameter,
9. A stainless Steinmann pin, 15 cm. long, 4 mm. in diameter (Vol. I/figs. 126—128) or a stainless wire (Vol. I/figs. 129—136),
10. A protective cap for the nail,
11. A sterile cloth,
12. A rotating stirrup for the nail (Vol. I/figs. 127, 128) or tension stirrup for the wire (Vol. I/figs. 129—131),
13. A hammer to drive in the nail (Vol. I/fig. 128) or a hand drill (Vol. I/figs. 132, 133), an electric drill (Vol. I/figs. 134—136) or a pneumatic drill (Vol. I/fig. 1696),

Warming of the patient, treatment of shock, physical examination, local anesthesia of the fracture sites and the roentgenograms are carried out as described on pages 1705, 1706

Application of the Long Leg Plaster Cast Prior to application of the cast a cord should be laid from the toes to the thigh as described on page 1656 Over it the full leg cast is applied to the horizontal (fig 2175) or hanging extremity (see pp 1724, 1725)

Check Roentgenograms Roentgenograms are then taken in both planes

Splitting of the Plaster Cast It is most important to split the plaster cast immediately (before the patient leaves the plaster room) throughout its full length and down to the last thread to avoid circulatory disturbances It is not enough to cut the cast at its proximal or distal end if pain sets in and the toes turn blue This may be followed by severe ischemic disturbances

Closure of the Split Long Leg Cast If the swelling of the lower leg begins to subside 2 to 3 days later the split cast is closed with a gauze or cotton bandage in order to avoid angulation This bandage should be drawn tight a few days later if it has become loose

Application of the Long Leg Walking Cast If, after 10 to 14 days, the swelling of the lower leg has completely disappeared a long leg plaster cast is applied, as described on pages 1724, 1725, which is not split In fractures without displacement the cast may be removed 8 weeks after the injury Further treatment with Unna s boot and elastic bandage are carried out as described on page 1733

Treatment of Closed Fractures of the Shafts of the Tibia and Fibula by Continuous Traction

According to my experiences from some thousand cases since 1916, continuous calcaneus pin or wire traction weighted with not more than 3 Kg within the first 3 to 4 weeks and elevation of the leg on a well dressed lower leg splint have proved the best method of treating fractures of the tibia and fibula To both surgeon and patient this method of treatment is the most comfortable, the quickest and the least dangerous and will give best results When performed properly the patient will be free from pain immediately or within a few days Circulation is never impeded If the materials have been properly prepared it takes only a few minutes to apply traction properly This treatment will not interfere with other hospital routine activity No circulatory disturbances, infection, deformity or non-union will develop if this treatment is properly carried out

Ordering the Bed and the Equipment Necessary for Traction When a patient is admitted to hospital with the diagnosis fracture of the tibia and fibula and a preliminary quick examination confirms this diagnosis one should immediately order an adequate bed with firm support, a well dressed lower leg splint, a radiant heat cradle, a set of weights of 3 Kg and a traction cord Then the operating room should be informed to arrange all that is necessary for traction (see p 1705) and to bring the sterile covered instrument table for local anesthesia (see Vol I/p 119 and fig 125) into the examination room as soon possible

because there is no room for the swollen mass of the calf But if the splint is properly bandaged and the shortening corrected by traction, the proximal fragment spontaneously falls into place and the angle (open behind) between the fragments disappears (figs 2377, 2378)

Careful Examination of the Roentgenograms The roentgenograms are displayed in such a way that the surgeon can always refer to them during operation According to the type of fracture and kind of injury the most suitable method of treatment is chosen, i e, one will decide whether the fracture should be first reduced by manipulation, or whether traction should be established without previous reduction

Insertion of the Pin or Wire As soon as the sterile pin or wire and the necessary equipment have been prepared the patient is placed in a warmed bed with the leg on a lower leg splint To have the heel well accessible, a foam rubber or cellulose roll covered by a sterile cloth is placed underneath the tendo Achillis An assistant should firmly hold the foot just proximal and distal to the ankle joint As the patient may become frightened when the pin or wire is being inserted, a towel should be hung up before his eyes The pin or wire is inserted transversely and not obliquely through the calcaneus On page 1667 we described precautions to avoid failures If the skin is drawn in medially and pushed out laterally it should be smoothed with the fingers The pin sites are left free and not covered with a dressing

Application of the Rotating Stirrup and the Pin Cap When the pin has been inserted the rotating stirrup (figs 127, 128) is applied and the pointed end of the pin is covered by a protective metal cap If no such cap is available a piece of cork is used and fastened with adhesive tape to prevent injuries

Pin, Wire or Clamp for Traction? It has been discussed, in Vol II/pp 1184—1187, why, in general, we prefer pins to wires or clamps for traction

Should Skeletal Or Skin Traction Be Used in Recent Fractures of the Tibia and Fibula As severe edema and sometimes blebs may develop in fractures of the lower leg bones, skeletal traction by pin through the heel is to be preferred to traction by adhesive tape, Hackenbruch s clamps, or Ruckert s slings on the ankle In the last named device there is danger of causing deep pressure sores which may extend down to the tendons Adhesive tape traction must be fixed by circular turns of bandage which may become too tight and impede circulation if applied within the first hours after the injury Moreover, adhesive tape often causes blebs Traction from a transfixion pin in the heel leaves the whole lower leg visible, and there is no pressure exerted on the skin Application of skeletal traction is an easy procedure and can be performed within a few minutes

Reduction More than 50% of all fractures of the lower leg bones show no considerable lateral displacement shortening or angulation (figs 2373 d—f, m—p) and require no reduction Manual reduction prior to the use of traction is necessary in cases with shortening of more than 1 cm and lateral displacement exceeding one third the width of the tibial shaft and/or angulation (figs 2373 g h, q—t, 2378 f—m, 2402—2409) This can generally be achieved easily and with but little force by pulling at the rotating stirrup mounted on the pin

14 A wooden box, 25 × 30 × 40 cm or 10 × 30 × 40 cm in size (Vol I/fig 118, figs 2374, 2375),
15 Steps or two wooden blocks to raise the foot of the bed (Vol I/figs 118, 119), or adjustable bed frame (Vol II/figs 1609, 1610),
16 Three weights of 1 kg each (Vol I/fig 118, fig 2374),
17 A strong hemp cord, 1 M long and 5 to 6 mm thick (fig 2374),
18 Unna s paste (50 Gm), a pot and a 10 cm wide brush (Vol I/fig 151),
19 A gauze bandage, 10 cm × 10 M , or
20 Adhesive tape, 60 × 5—6 cm with a perforated 6 × 6 cm wooden spreader (Vol I/fig 695),
21 Mastisol (skin adherent)

For lateral traction and pressure are needed —

1 A lateral support with a pulley (Vol I/fig 111, fig 2375),
2 A stockinet tube slightly padded with cotton 10 × 50 cm , with wooden spatulae sewn in at both ends (fig 2375),
3 A small wire stirrup (Vol I/fig 147, fig 2375),
4 Two weights of 0 5 kg each

Local Anesthesia of the Fracture Sites and the Pin Sites After a rapid physical examination the fracture sites of the tibia and fibula which can easily be located from the swelling and tenderness, are rendered insensitive by injecting 20 ml of a 2% Novocain solution The pin sites, two finger-breadths behind and below the tips of the malleoli, are marked by the uncovered end of the wood applicator sticks (Vol I/fig 152), painted with tincture of iodine and made insensitive by injection of 5 to 10 ml of a 2% Novocain solution

Marking the Fracture Sites with a Red Cross The fracture sites are marked with a red cross by a skin pencil so that the roentgen technicians know where exactly to focus the central ray and where to place the roentgen film

Roentgen Technique The roentgenograms should be made in both main planes, i e , exactly from in front and exactly from the side This is easy if the fracture sites have been anesthetized

Checking the Equipment Quoted on page 1705 At first the bed is checked to see if it fulfills the conditions given in Vol I/p 95 with special attention to the fracture boards throughout the full length and width of the bed and the firmness of the hair mattresses to provide firm support for the lower leg splint It is interesting to learn that some hospital administrators do not give their consent to buy fracture boards Correct positioning of the patients is impossible without them

Bandaging the lower leg splint is carried out as described in Vol II/p 1183 and shown in figures 2374 and 2378 It should be made a special point that enough space is afforded for the severely swollen calf

If the leg is laid on a flat splint the calf muscles which are markedly swollen, will press the proximal fragment forward and cause antecurvature, an obstinate form of displacement which was recognized by Malgaigne who attempted to press the proximal fragment back into position by a specially designed screw (fig 2376) It can be seen from the diagram that this is impossible because the shortening and overlapping have not been corrected, and also

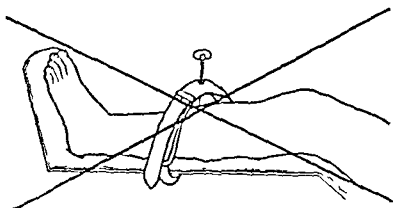
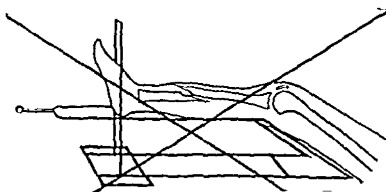
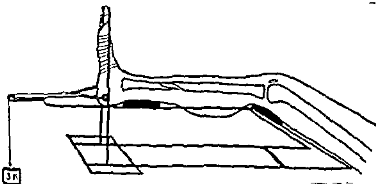


Fig 2376 —Malgaigne's pressure stirrup



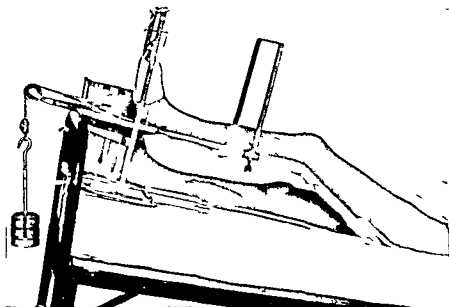
Sketched in 1917

Fig 2377 —Bad position of a fracture of the lower leg bones which results from a loose bandage at the knee and a taut bandage under the calf The knee sinks the proximal fragment is tilted forward and may pierce the skin Circulation may be impeded Absence of pin traction and of suspension of the foot while the foot hangs in drop foot position causes pressure on the heel and outward rotation of the distal fragment



Sketched in 1917

Fig 2378 —Correct position for a fracture of the lower leg Pin traction with a pad under the knee loose bandage sling under the calf pad under the tendo Achillis and suspension of the fore foot The forward displacement of the proximal fragment disappears with the pad under the knee and the loose bandage sling under the calf as soon as shortening has been decreased to 3 to 5 mm by longitudinal traction The pad under the tendo Achillis and suspension of the fore foot prevent sores on the heel or rotation of the distal fragment At present we usually use no pads under the knee and the tendo Achillis



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Fig 2374 —Fracture of the tibia and fibula in calcaneus pin traction weighted with 3 Kg boards under the hair mattresses throughout the length and width of the bed so that the lower leg splint cannot sink down at the buttock The foot of the bed is raised 30 cm Position of the leg on a well bandaged lower leg splint The bandaging should begin at the transverse bar of the splint and end proximal to the heel so that it lies free At the angle for the knee and proximal to the heel the bandage should be drawn tight but at the calf the turns of the bandage should be looser so as to afford space for swollen calf The fore foot is suspended on the U support of the splint to avoid equinus position and rotation The fore foot suspension is kept apart by a wooden spreader to allow for free motion of the toes This suspension sling als serves to correct angulation in the sagittal plane A supplementary U support protects the lower leg from pressure of the blanket The sound foot is propped against a wooden box

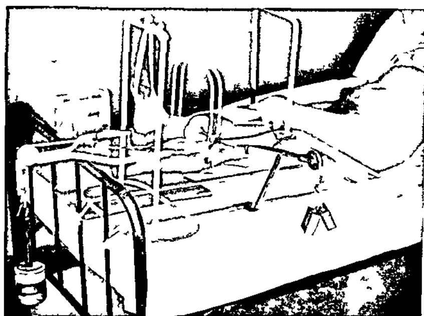
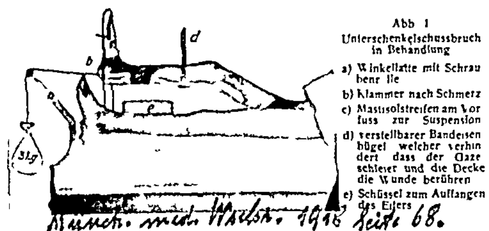


Fig 2375 —Lateral traction by means of a padded stockinet sling with tongue blades sewn in at its ends and a small iron spreader weighted with 1 Kg An aluminum hoop (after Bartmann) with a well padded aluminum pad for lateral pressure is applied distal to the middle of the lower leg Lateral traction and pressure serve to correct separation of the fragments in the frontal plane Lateral traction *or* pressure is as a rule sufficient to correct angulation in the frontal plane The mattresses are slightly too soft so that the splint gives at the buttock

apply no plaster cast after reduction of a recent, closed fracture of the shafts of tibia and fibula

From 1929 to 1936 we reduced most fractures of the tibia and fibula with displacement in the screw traction apparatus and applied a plaster cast at once At present we use the screw traction apparatus in only 5 to 10% of all fractures of the tibia and fibula

Immobilization If the fragments have not been displaced, or have been apposed either manually or in the screw traction apparatus, immobilization is performed by traction weighted with 1—3 kg, a rotating stirrup and a cord are used (figs 2374, 2375), the foot is suspended by slings fastened to both ends of the pin (fig 2378 c)



2378 e (taken from Münch med Wschr 1918 p 68

Fig 2378 e—Position of a gunshot fracture of the lower leg bones in continuous traction This illustration was made in spring of 1917 The traction weights of 3 kg were too heavy for an open fracture with extensive injury to the muscles Therefore pes calcaneus resulted

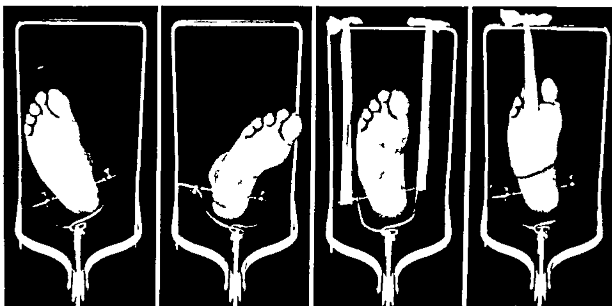
U-support for the Blanket Over the middle or proximal third of the lower leg a supplementary U-support is fixed to keep the blanket off the lower leg (fig 2374) A muslin veil is drawn over both stirrups (it is not shown in fig 2374)

Another Stirrup for Too Short or Too Long Lower Legs If the lower leg is short, the foot can only be suspended in drop-foot position on a normal lower leg splint To avoid this a second stirrup is applied proximally (or distally in a too long lower leg) so that the fore-foot will hang vertically (fig 2485)

Aluminum Hoop (after Bartmann) in Unstable Fractures In fractures with severe lateral displacement which are prone to re-displacement after reduction, a Bartmann aluminum hoop with a well padded cushion for the medial side of the fracture is applied to the lower leg splint in order to maintain good position Special care should be taken that this hoop is placed correctly i e on the proximal fragment in external rotation fractures (fig 2373 d, e) on the distal fragment in internal rotation fractures (fig 2373 f), or on the proximal fragment in flexion fractures with a lateral flexion wedge

Reduction in the Presence of Local Circulatory Disturbances Reduction is especially urgent if the foot is blue or cold, a sign of compression or rupture of the vessels, as in the case shown in figure 2378 f Reduction can be achieved by longitudinal traction and pulling the distal fragment anteriorly

Reduction in the Presence of Separation in the Long Axis (Diastasis) Reduction must be performed especially carefully in fractures with pronged fracture surfaces and longitudinal separation as shown in figure 2378 h If reduction cannot be achieved by mere traction, one fragment is angulated on the other as shown in Vol I/figs 16—18 In some cases an additional slight rotation is necessary



2378 a 2378 b 2378 c 2378 d

Fig 2378 a —*Absence of suspension has led to external rotation of the foot*

Fig 2378 b – Absence of suspension has led to internal rotation of the foot

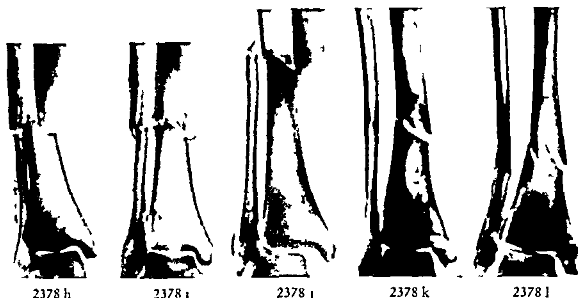
Fig 2378 c —The foot is correctly suspended at both ends of the pin so that the inner side of the foot is vertical and the ball of the great toe and the heel are equidistant from the vertical bars of the stirrup

Fig 2378 d —The fore foot is correctly suspended by an Unna s paste bandage so that the inner side of the foot is vertical

Reduction in the Screw Traction Apparatus If manual reduction cannot be achieved in cases with displacement by a full shaft s width and shortening (figs 2373 h 2378 k), the patient is placed in the short screw traction apparatus A spring scale is inserted between the stirrup and the hook of the screw (fig 2410) Traction of 5—6 Kg will generally be sufficient to correct the shortening, as well as angulation and lateral displacement If the fragments do not slip into place by themselves when shortening has been overcome, they can usually be apposed by slight pressure Roentgen fluoroscopy (fig 2411) confirms the result of reduction If a fracture with displacement by a full shaft s width proves unstable after reduction it is expedient to insert a medullary wire to avoid re-displacement (figs 2458—2466) In general, we

Unna's Paste Traction for the Fore-foot Instead of adhesive tape we have for many years been using Unna's paste traction which is applied in a similar way as in fractures of the femur (Vol II/p 1196), but with the one difference that the strip of bandage is not wound round the heel but cut in two and led over the extensor and flexor sides of the third toe (fig 2378 d)

Determination of the Traction Weights for Pin or Wire Traction In heavily-muscled patients 3 kg are chosen (figs 2374, 2375), in weakly-muscled patients



2378 h 2378 i 2378 j 2378 k 2378 l

January 3 1953 March 13 1953

Fig 2378 h —Transverse fracture of the tibia and the fibula with serrated fracture surfaces of the tibia There is separation of the tibial and fibular fragments in the long axis since the fragments cannot approach each other because of the prongs Manual reduction by traction on the calcaneus pin and impaction of the fragments was done Continuous calcaneus pin traction for three weeks followed by a long leg walking cast for another seven weeks

Fig 2378 i Same case ten weeks later The fracture healed in a very satisfactory position Firm union clinically The fracture line is still visible in the tibia No pain on weight bearing Such fractures would better be immobilized for 12 weeks

Fig 2378 j Transverse bending fracture of the tibia and fibula at the junction of the middle and distal thirds fracture of the lateral malleolus with lateral subluxation of the foot Produced by the impact of a heavy object on the lateral aspect of the lower leg in a 48 year old lumberjack In such cases one should try to bring the tibial fragments into apposition by traction on the calcaneus pin If this fails a wire is drilled through the tibia 5 to 7 cm proximal to the ankle joint By traction on this wire the fragments are apposed in the long screw traction apparatus (fig 2348) As soon as the lateral displacement has been corrected traction is released to allow the fragments to approach each other In our patient after correction of the subluxation a long leg cast was applied and split immediately throughout its full length After 2 to 3 weeks a long leg walking cast was applied for an additional nine weeks

Fig 2378 k —Oblique bending fracture of the tibia at the upper end of the distal fourth avulsion fracture of the internal malleolus Produced by the impact of a filled 450 liter (100 gallons) barrel on the lateral side of the lower leg of a 29 year old butler The fracture was reduced by adduction of the lower leg and a long leg cast was applied which was split at once 8 to 10 days later a long leg walking cast was applied for another 8 weeks

Fig 2378 l —Oblique fracture of the tibia and fibula at the distal fourth of the lower leg fracture of both malleoli without significant dislocation Sustained by a 19 year old unskilled worker who was crushed between two wagons Reduction and immobilization as in the case of fig 2378 k

(figs 2373 q, r), and on the distal fragment in the rare cases of flexion fractures with a medial flexion wedge

Raising the Foot of the Bed When the patient has arrived in the ward the foot of the bed is raised on steps (Vol I/figs 118, 119, Vol II/fig 1604 a) or wooden blocks, or the foot of the metal frame is raised (Vol II/figs 1609 a 1611), in order to counteract the traction weights which tend to pull the patient distally



2378 f May 15 1955 2378 g May 15 1955

FIG 2378 f —Infracondylar fracture of the left tibia and fibula with posterior displacement of the distal tibial fragments by the full width of the shaft The toes were blue and could not be moved actively Capillary blood did not flow back after pressure on the toe nails The dorsum of the foot was pale mottled and cold No pulses were palpable in the foot Sustained by a 19 year old motorcyclist who collided with a truck Simultaneous fracture of left femur and subtalar dislocation of right foot Immediate reduction of the lower leg bones by longitudinal traction and forward pull of the distal fragment Thereupon the foot became red within a few minutes and the pulses became palpable The pressure of the displaced fragments on the tibial arteries was removed

FIG 2378 g —Same case after reduction and insertion of pins through the femur and the calcaneus for traction in the long axis Moreover a wire has been drilled through the proximal end of the distal tibial fragment for ventral (anterior) traction

Fastening the Lower Leg Splint to the Foot of the Bed The lower leg splint should be fastened to the vertical bars of the lower end of the bed so that it cannot move

Wooden Box for the Sound Foot The wooden box should be of such a size that the sound foot is propped against it (with the knee extended) when the knee of the injured limb lies at the knee angle of the lower leg splint (figs 2374 2375)

Adhesive Tape Traction for the Fore-foot To prevent the foot from rotating and sinking into drop foot position the fore foot is suspended by adhesive tape as described in Vol II/p 1258

Among the patients who were admitted to our hospital with delayed union or non union Jahna and Schärizer[1] found five cases where traction of 18—20 kg had been used

Analgesia In our treatment pain is as a rule, slight from the beginning If pain is felt to be due to tension of the blood effusion we give a hypnotic or analgesic the first two or three nights If the skin of the lower leg feels hot, moist compresses are an effective relief

Questions We Should Ask Ourselves in Order to Avoid Failures When Treating Closed Fractures of the Shafts of the Tibia and Fibula by Traction

1 Have I treated the shock before carrying out the physical and roentgen examination?
2 Have I promptly warmed a shocked or cold patient with warm blankets warm drinks and warm air?
3 Have I used local anesthesia to combat the shock?
4 Have I anesthetized the medial and lateral side of the calcaneus?
5 Have I given blood or plasma in time if warming the patient and local anesthesia failed to relieve shock?
6 Have I, when the diagnosis has been made, immediately ordered all that is required for treatment according to the list on page 1705?
7 Have I answered all the general questions given in Vol II/p 1148, for dislocation of the hip?
8 Have I marked the fracture site with a red cross to facilitate positioning of the roentgen films?
9 Have the roentgenograms been made exactly from in front and exactly from the side?
10 Have I checked all equipment required for treatment, for completeness and quality while the roentgenograms are being developed?
11 Have I examined whether the fracture boards under the hair mattresses have been placed correctly (Vol I/fig 99)?
12 Have I examined whether the hair mattresses have been packed tightly enough (figs 2374, 2375)?
13 Has the bed been warmed by a radiant heat cradle?
14 Has the lower leg splint been bandaged properly (see Vol II/p 1243 and fig 2378)?
15 Have I used standard weights of 1 kg (Vol I/fig 118, figs 2374, 2375)?
16 Have I placed the weights on a weight-carrying rod and not fastened them with a string?
17 Have I carefully studied the roentgenograms to choose adequate treatment?
18 Have I after inspection of the roentgenograms, placed the patient with the lower leg splint in the warmed bed?
19 Have I placed a foam rubber or cellulose roll under the heel to have good access for insertion of the pin or wire?

[1] Jahna and Schärizer Kritik der Behandlungsergebnisse bei 1432 von 1926—1950 veralter in das Unfallkrankenhaus Wien eingelieferten geschlossenen und offenen Unterschenkelschaftbruchen 1956

2 or only 1 Kg In stable transverse fractures not more than 1 Kg should be applied after reduction (figs 2378 h, i, 2459, 2462), this serves to avoid angulation but causes no distraction (separation in the long axis) Pes calcaneus, as shown in fig 2378 e, is always a sign of excessive traction weights In that case even 3 Kg were too much Only standard weights should be used which can be changed easily if necessary The kind of weights to be used has been accurately described in Vol II/p 1180 If more than 3 Kg are used for longitudinal traction of a closed fracture of the shafts of tibia and fibula, an interfragmentary gap (distraction) will result The gap between the fracture ends will fill with blood which will organize in time When the necrotic fracture ends are being resorbed from the third week on, a gap will remain which can no longer be bridged The muscle pull can no longer draw together the separated fracture ends if excessive weights are being used Meanwhile, from the fourth week on, the fibula becomes so firmly united that it will act as a strut which prevents the tibial fragments from coming together The use of excessive traction weights has caused enormous damage these last decades Delayed callus formation and frequent occurrence of non-union, dystrophy, muscular atrophy, and limitation of motion (see Vol I/pp 25—27), can almost always be traced back to operative treatment or to continuous traction by excessive weight which has been kept up for weeks, and not to hormonal disorder, vitamin deficiencies, and other mysterious causes When seeing roentgenograms in various magazines and books, one finds gaps between the fragments (see M N /figs 352—365) which are downright alarming But authors however, like to present them as proof of the efficiency of longitudinal skeletal traction It is, however, not a question of pulling as hard as possible, which will only be harmful, but a question of applying traction in a correct manner and this is carried out in closed fractures of the tibia and fibula by elevation of the leg on a lower leg splint and traction weights of 3 Kg, sometimes of 2 or even 1 Kg

As consultant surgeon to the health insurance companies of trade guilds I visited 52 hospitals in 1940 I found only four surgeons who used a traction weight of 3 Kg in fractures of the tibia and fibula 48 used weights of 4—10 Kg

Case History Figures 2390 and 2391 show the after effects of treating a fractured tibia and fibula with continuous traction of 15 Kg for six weeks in another hospital Not only were the fragments drawn apart but also the muscles nerves and vessels were overstretched The patient was again and again pulled off the splint and had to be brought back into correct position several times a day Due to overstretching of all tissues he was in constant pain *Because of pain circulation was impeded and this in turn resulted in a low calcium content* As this torsion fracture of the tibia was exceptionally accompanied by a transverse fracture of the fibula the fibula did not unite This caused the fragments to slide over each other as much as 3 cm after removal of the heavy traction weights After treatment consisted of two hours of massage daily painful passive motions hot baths and short wave therapy In the case history was found the remark Treatment according to Bohler When th patient w s admitted to our clinic 18 weeks after occurence of the injury the leg was massively swollen Toes ankle and subtalar joints could be moved only with painful shaky movements Knee joint 160°—130° Patient could walk only with the help of two crutches With elevation the swelling of the leg subsided within ten days Then a long leg walking cast was applied for ten weeks Bony union and good alignment was achieved Two years later the bone density was again normal (figs 2392 2393)

43 Has an Unna's paste or adhesive tape traction been applied to the fore foot?
44 Have I insured that the traction weights will not get caught on the bed or will not rest on a chair thus becoming ineffective?
45 Have I ordered an analgesic and moist compresses to the lower leg if pain is felt in the first two or three nights

Further Treatment of the Closed Fractures of the Shafts of Tibia and Fibula by Means of Skeletal Traction

The daily observation of the general condition and the checking of the traction weights are carried out as for fractures of the femur (see Vol II/p 1200)

Checking the Position of the Leg The lower leg splint should be checked daily to see if it is level and not tilted towards the center of the bed, if the splint is well bandaged, if the heel lies free, and if the sole of the foot is at a right angle with the lower leg or shows a few degrees of plantar flexion Under no circumstances should there be calcaneus position or rotation of the foot The inner border of the foot should be vertical, i e, parallel with the vertical bars of the lower leg splint (figs 2378 d, e) The pin sites must be kept under daily observation although reddening or inflammation are but rare One should ascertain that the lower leg shows no angulation neither in the sagittal nor in the frontal plane One should practice to recognize angulation without fluoroscopy or roentgenograms

The fracture site is marked with a red cross, and red lines are drawn to indicate desired positions for upper and lower edges of the cassettes, in the same way as for fractures of the femur (see Vol II/p 1201)

First Roentgen Check On the second, or on the third day at latest roentgenograms must be taken in both planes, first to see whether a gap (diastasis) might have formed between the bone ends, secondly to determine the type and amount of angulation and lateral displacement

Correction of Diastasis If a diastasis in the long axis of the bone should have developed, 1 Kg is taken away

Correction of Angulation in the Sagittal Plane In the case of antecurvature (with an angle open posteriorly) the foot suspension is adequately raised in the cases of recurvation (with an angle open anteriorly) it is lowered

Correction of Angulation in the Frontal Plane In varus (with an angle open medially) the traction cord will be fastened eccentrically at the medial side of the traction stirrup as shown in Vol II/fig 1993 In valgus position (with an angle open laterally) the traction cord will be fastened eccentrically at the lateral side of the stirrup as shown in Vol II/fig 1995 In general angulation up to 10° can thus be corrected In the case of a more severe angulation a pad should be applied to the lateral (or medial) side of the lower leg in varus (or valgus) respectively Lateral traction (fig 2375) should only be used after the swelling has subsided, in order to avoid circulatory disturbances

Treatment of Lateral Displacement of more than a Third of the Width of the Shaft If after one week, there is lateral displacement of more than a

20 Have the eyes of the patient been covered to prevent him from seeing the insertion of the nail?

21 Has the foot been firmly held proximal and distal to the pin sites for insertion of the pin?

22 Has the pin been driven through transversely and not obliquely?

23 Have I smoothed the skin with fingers to avoid circumscribed necrosis if it was drawn in medially and/or pushed out laterally?

24 Have I left the pin sites free from bandage so that they can be inspected and inflammation can be recognized at once on rounds?

25 Have I used a rotating stirrup?

26 Have I put a metal cap with a set screw or a piece of cork over the pointed end of the pin so that no one can be injured?

27 Have I arranged all set-screws in the same direction?

28 Have I, prior to application of the traction weights, manually reduced those fractures of the tibia and fibula where shortening of the tibia amounts to more than 1 cm and lateral displacement is more than one third of its shaft's width?

29 In the presence of circulatory disturbance have I carried out reduction at *once and applied traction ventrally to a wire through the proximal* fragment of the tibia?

30 Have I accurately reduced and impacted the fragments which showed longitudinal separation?

31 Have I reduced the fragments in the screw traction apparatus if manual reduction failed?

32 Have I avoided using more than 3 Kg for longitudinal traction, since this causes distraction of the fragments with subsequent delayed callus formation, non-union and all the other complications described in Vol I/pp 26—27 and in M N [1]/pp 90—144

33 Have I weighted the traction with only 2 or 1 Kg in asthenic patients?

34 Have I weighted the traction with only 1 Kg in stable, well-reduced transverse fractures?

35 Have I at once diminished the traction weight if *pes calcaneus* (fig 2378 e) has developed?

36 Has a supplementary U-support been applied on the lower leg splint to keep off the blanket?

37 Has another supplementary U-support been attached in the case of an unusually short or long lower leg?

38 Have I suspended the foot at the calcaneus pin in such a way that the inner side of the foot is vertical (figs 2378 c d)?

39 Have I mounted a Bartmann aluminum hoop with a well lined pad in unstable fractures?

40 Have I raised the foot of the bed 30 cm?

41 Has the lower leg splint been fastened to the foot of the bed?

42 Has a wooden box been provided for the sound foot?

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[1] Bohler L Medullary Nailing of Kuntscher translated by Hans Tretter Baltimore Williams & Wilkins 1948

10 Have I daily checked that the lower leg is straight and shows no angulation?
11 Have I daily checked that the lower leg splint is level?
12 Have I daily checked that the lower leg splint has remained well bandaged (see Vol II p 1163 and figs 2374 2378)?
13 Have I ordered packing the hair mattresses more firmly if they sagged from the patient's buttocks and if the lower leg splint slanted?
14 Have I daily encouraged the patient to prop his sound leg against the wooden box?
15 Has the patient daily performed active exercises of the toes *through their full range*?
16 Have movements of the ankle been omitted?
17 Has quadriceps drill been omitted to avoid displacement of the fragments?
All these questions can after some training, be answered easily within 30 seconds or one minute
18 Have I taken roentgenograms in both planes on the second or on the third day at the latest to exclude a gap between the fracture ends and angulation?
19 Have I made roentgenograms after one week, at the removal of the traction weights and at the end of the treatment?
20 Have I marked the skin over the fracture site with a red cross to help the roentgen technician in centering the central ray?
21 Have I marked the upper and lower edges of the area to be included on the film with lines on the skin to indicate to the roentgen assistant what size film she should use and where she should place the cassette?
22 Have I reduced the traction weights if separation in the long axis (longitudinal diastasis) has developed?
23 Have I in the case of lateral separation of the fragments (lateral diastasis), applied a lateral pad at the correct place and added lateral traction one week later?
24 Have I raised or lowered the fore-foot traction in angulation in the sagittal plane?
25 Have I raised the fore-foot traction in antecurvature?
26 Have I lowered the fore-foot traction in recurvation?
27 Have I fastened the traction cord eccentrically if angulation in the frontal plane amounts to less than 10°
28 Have I used eccentric traction at the medial side in varus deformity (Vol II/fig 1993)?
29 Have I used eccentric traction at the lateral side in valgus deformity (Vol II/fig 1995)?
30 Have I used a lateral pad or lateral traction if angulation in the frontal plane amounts to more than 10° (fig 2375)?
31 Have I marked all necessary data on the patient's overhead blackboard?
32 Have I entered all changes of traction weights and all corrections of angulation in the temperature chart and the case history?
33 Have I on the weekly Grand Rounds checked all entries on the patient's blackboard and temperature chart and reviewed all serial roentgenograms?
34 Have I removed the traction weight in torsion fractures after three weeks

third of the width of the shaft, a pad is applied laterally and at the same time lateral traction of 1 kg is exerted (fig 2375) In order to position the lateral pad and lateral traction at the proper place it is important to have the center of the fracture site marked with a red cross

The patient's overhead board and his temperature chart are kept, and rounds are made, as for fractures of the femur (see Vol II/p 1202)

Treatment of Tension Blisters Blisters which have developed in a case of severe displacement, due to tension from a big hematoma, are usually left until they dry up If they cause pain they are opened with scissors or a needle at their most dependent point The wall of the blister is not removed to avoid weeping eczema

Exercises The toes should be actively moved through their full range from the first day on In paralysis of the peroneal nerve a strip of bandage is used by the patient so that he himself can pull the toes up The paratalar joints should not be moved Contraction of the quadriceps (as practiced in femoral fractures) should not be carried out in fractures of the tibia and fibula since this lifts up the proximal fragment and irritates the site of the fracture

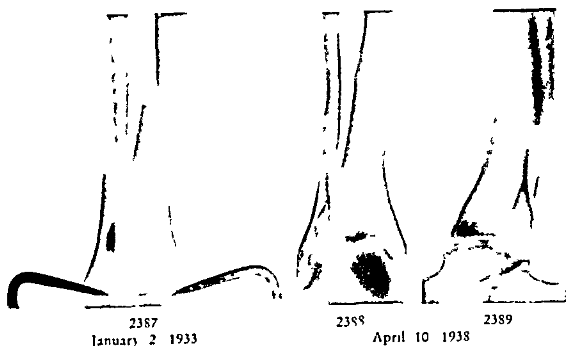
Second and Third Roentgen Check New roentgenograms in both planes should be made after one week and after three weeks In more severe displacements more roentgen checks will be necessary

Duration of Immobilization in Treatment by Traction In general, torsion fractures are kept in traction for three weeks, angulation fractures for four weeks If after that time the traction weights are removed and the patient is told to raise his leg, he can usually do so and the fracture will not bend, provided care has been taken to avoid excessive traction weights, and that a shortening of 1 to 5 mm has always been present A long leg walking cast follows

If there is shortage of hospital beds or if the patient requests urgently to be discharged the long leg cast may be applied as early as 8—10 days after the injury but he must not start weight bearing earlier than three weeks after the accident

Questions We Should Ask Ourselves in Order to Avoid Failures When Treating Closed Fractures of the Shafts of the Tibia and Fibula by Traction

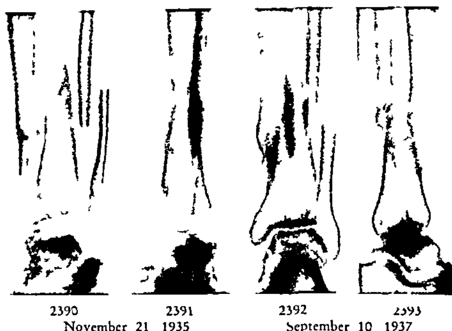
1 Have I daily checked the patient's general condition?
2 Have I daily inspected the patient's legs with the blankets off?
3 Have I daily checked the patient's temperature and pulse charts?
4 Have I checked daily that not more than 3 kg are used for longitudinal traction?
5 Have I daily checked that the traction weights have not been caught or arrested anywhere?
6 Have I daily checked whether *pes calcaneus* has developed which is *a sign of excessive traction* (fig 2378 e)?
7 Have I daily checked to see that the inner side of the foot is vertical (fig 2378 d)?
8 Have I daily checked to see that the heel lies free?
9 Have I daily checked whether the pin sites are dry and free from reaction?



2387 January 2 1933 2388 2389 April 10 1938

Fig 2387 Torsion fracture of the lower halves of the tibia and fibula treated in another hospital with a clamp which had been inserted into the ankle joint and left in place for four weeks A walking cast was applied without correction of the recurvation

Figs 2388 2389 Same case five years later United with 20° recurvation The joint space of the ankle joint is very narrowed there are arthrotic marginal exostoses at the front of the talar and at the back of the subtalar joint Arthrosis has developed due to irritation of the clamp and has become worse because of angulation Pain on walking



2390 2391 November 21 1935 2392 2393 September 10 1937

Figs 2390 2391 —Torsion fracture of the lower halves of the tibia and fibula in a 36 year old man He was treated at another hospital with calcaneus wire traction weighted with 15 Kg for six weeks Massage and passive movements hot baths and short wave therapy followed through twelve weeks The leg was severely swollen he could walk only with the aid of crutches The fracture was still mobile Lateral displacement the full width of the tibial shaft shortening of 3 cm Severe decalcification Such severe shortening occurs in torsion fractures only when excessive traction by heavy weights has been exerted for a long period of time

Figs 2392 2393 —Same case two years later The swelling of the lower limb subsided on elevation within ten days A walking cast followed for ten weeks Bony union without angulation was achieved Shortening of 3 cm



2379 2380 2381 2382
April 15 1937 April 24 1937

FIGS 2379 2380 Half torsion fracture at the junction of the middle and lower thirds of the tibia torsion fracture cranial to the middle of the fibula Shortening and lateral displacemen by the full width of the tibial shaft

FIGS 2381 2382—Same case one week later Treated with calcaneus pin traction of 3 Kg Shortening and lateral displacement have been corrected by continuous traction in the long axis As a rule it is better to reduce such a fracture first by manual longitudinal traction exerted at the calcaneus pin and then to continue with continuous traction



2383 2384 2385 2386
April 25 1937 February 28 1938

FIGS 2383 2384—*Open* torsion fracture of the lower third of the tibia closed torsion fracture of the lower third of the fibula Severe comminution of the tibia The large torsion wedge is rotated through 90° so that the fracture surface faces the skin

FIGS 2385 2386—Check roentgenograms re figs 2383 2384 ten months later Bony union of the fragments in good alignment Patient can walk well



2402 2403
December 20 1936

2404 2405
December 27 1936



2406 2407
February 28 1937

2408
June 15 1937

2409
August 8 1955

FIGS 2402 2403 Torsion fracture of the tibia and the fibula at the junction of the middle and the lower thirds Valgus of 15° and recurvation of 22° shortening of 2 cm Sustained by a 30 year old hotel proprietor while skiing

FIGS 2404 2405 Same case seven days later in calcaneus pin traction weighted at first with 4 Kg as an exception then with 3 Kg Angulation has disappeared Lateral displacement by a third of the width of the tibial shaft Shortening of 4 mm It would have been expedient in this case to apply a pad at the lateral side of the distal fibular fragment and lateral traction at the proximal tibial fragment as in fig 2375 to correct the lateral separation

FIGS 2406 2407 Same case ten weeks later Treated by traction for four weeks and by a long leg walking cast for six weeks Callus formation visible only at the upper end of the fracture cleft The fracture is clinically firm Lateral displacement by half the width of the tibial shaft shortening of 4 mm axis of the tibia straight

FIG 2408 —Same case six months later Fracture cleft still open in the center Asymptomatic he can perform all sports 15 weeks after the accident he rowed 85 Km up the Danube Free active motion of all joints

FIG 2409 —Check roentgenogram re figs 2402—2408 19 years later The hole in the center of the fracture cleft is still present Varus of 5° Has always been asymptomatic No arthrosis



2394 2395
March 9 1937

2396 2397
March 16 1937

2398 2399
May 14 1937



2400 2401
September 17 1937

Figs 2394 2395 — Torsion fracture of the lower third of the tibia torsion fracture of the upper third of the fibula Sustained by a 32 year old surgeon who fell when skiing Shortening of 1 5 cm

Figs *2396 2397* — *Same case one week later in calcaneus pin traction weighted with 3 Kg Shortening of 0 5 cm*

Figs *2398 2399* — *Same case nine weeks later Treated with traction for four weeks and with a long leg walking cast for five weeks Although only cloudy callus was visible the fracture was clinically firm and the patient could bear his body weight without pain Shortening of 1 cm No decalcification of the ankle joint He could again take up tennis four months after the injury*

Figs 2400 2401 — Same case six months later Firm bony union normal external shape full active joint motion Asymptomatic At follow up examination 18 year later also asymptomatic

and carefully applied to the posterior side of the thigh from the flannel strip down, beyond the tips of the toes Then, two plaster bandages are wound around it A plaster splint, 75 cm long is cut into three equally long parts which are placed on the medial, lateral and anterior side of the knee joint The previously incised flannel strip is turned down at the upper end of the cast and then two or three plaster bandages are wound round the leg The last of these bandages serves to strengthen the toe plate of the cast

Application of the Long Leg Walking Cast with the Lower Limb Hanging The patient may also sit on the table and have the lower limb hanging down obliquely The surgeon is seated, in this case in front of the patient with the heel resting on the surgeon's knees The cast is then applied in the same way as with the leg in horizontal position

Fluoroscopy of the lower leg is quickly carried out in both main planes before the plaster has set If there is angulation it can still be corrected easily

First Roentgen Check in Plaster Roentgenograms are then made in both planes They usually show good position

Wedging of Plaster Casts in Case of Angulation If angulation amounts to more than 15° it is as a rule expedient to apply a new cast In angulation of from 3° to 15° the cast may be wedged if both lower leg bones are fractured In fracture of the tibia alone the cast must not be wedged as a decubitus ulcer may develop over the fibula *The patient must not be subjected to local or general anesthesia* The cast is cut on the concave side of the angle, i e, medially in varus and laterally in valgus angulation, level with the intersection of the axes of the main fragments (figs 2430—2433) The cut is made with a hand saw and exceeds half the circumference of the cast In the presence of varus with recurvation the cut is made anteromedially, in valgus with antecurvature lateroposteriorly If the patient is not anesthetized, there is almost no danger of injury to the skin as the tearing of the threads of the plaster bandages can be well noted especially in an unpadded plaster cast The cut in the plaster is opened to a wedge and held apart by a piece of cork The position of the fragments is checked by fluoroscopy in both planes If necessary, the degree of correction may then be increased or decreased When the axes of the fragments appear to be straight in both main planes roentgenograms are made If they show good alignment in both planes the gap in the plaster is carefully filled with an accurately fitted cellulose pad A 10 cm long plaster splint and a circular plaster bandage are placed over it We have given up excision of a plaster wedge (figs 2426—2429) since the skin often gets pinched and pain and decubital ulcers ensue

Trimming the Plaster Cast The edges of the cast must be cut in a way that the medial side of the big toe and the lateral side of the fifth toe remain covered by plaster This prevents early breakage of the toe plate The extensor side of the toes must be freed from plaster as far as the webs of the toes so that circulation can be well examined at all times Moreover, the toes can be actively moved upwards For this purpose also the extensor side of the first phalanx of the big toe must be exposed No plaster must be removed proximal to webs of the toes to avoid edema and painful decubital ulcers Even erysipelas may develop

and in flexion fractures in the course of the fourth week, and have I requested the patient to attempt active raising of his leg?

35 Have I applied a full leg walking plaster in torsion fractures after three weeks and in flexion fractures after four weeks, if the lower leg did not bend at the attempt at active raising?

Further Treatment of Closed Fractures of the Shafts of the Tibia and Fibula With a Long Leg Walking Cast

For application of the full leg walking plaster in addition to the materials necessary for removal of the calcaneus pin quoted on page 1515, the following are required

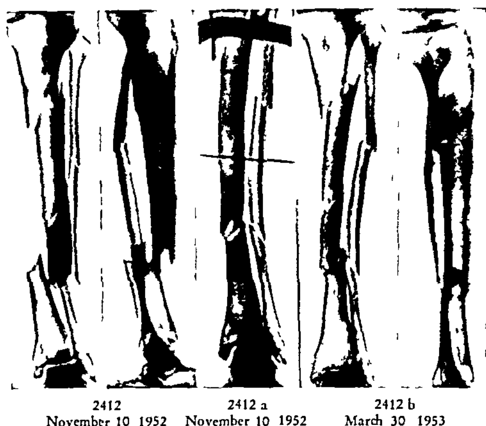
1 A third instrument table for the material,
2 Two sterile thumb forceps,
3 Four or five sterile sponges made of eight folds of gauze 4 by 4 cm,
4 Two sterile sponges made of eight folds of gauze 2 by 2 cm,
5 Benzene
6 Alcohol,
7 Tincture of iodine,
8 Peruvian balsam,
9 Mastic adhesive solution,
10 Cotton tipped applicators (Vol I/fig 152)
11 A pair of strong pliers (Vol I/fig 145)

Removal of the Calcaneus Pin For removal of the rotating stirrup the foot is firmly held by an assistant cranial to the ankle and at the dorsum The pointed end of the pin is thoroughly cleansed with benzene and alcohol and finally painted with iodine When the tip of the pin is perfectly clean the pin is pulled out with strong pliers This can be done easily and without pain if the foot is held firm and if slight rotation is carried out during the extraction There is as a rule but little bleeding The skin round the pin sites is dabbed with mastic adhesive solution and the 2 by 2 cm swabs with a drop of Peru balsam on each, are applied

Removal of the Calcaneus Wire If a wire instead of a pin has been used for traction it is cleaned and clipped flush with the skin and extracted The two skin holes are covered with small balsam of Peru swabs in the same way as after removal of a pin

Application of a Long Leg Walking Cast with the Lower Limb Horizontal The patient is positioned in the same way as for application of the plaster cylinder for the knee joint (fig 2175) An assistant stands on the sound side and supports the fracture site with one hand to avoid recurvation With the other hand he holds the big toe to prevent the foot from dropping and rotating The inner side of the foot must be vertical According to the site of fracture, either the middle or the upper third of the thigh is dabbed with a few strokes of mastic adhesive solution Round this part of the thigh a 5 by 70 cm *flannel strip*, cut in at one side is wrapped in such a way that its ends overlap at the lateral not the anterior side of the thigh The strip must not wrinkle A plaster splint 100 to 110 cm long is made of two plaster bandages

Cleansing the Toes As soon as the edges of the cast have been trimmed and before the patient leaves the plaster room the toes must be carefully washed and freed from plaster particles so that the circulation can properly be observed at all times If some hours elapse before the cleansing this will be very painful because the plaster particles which hardened in the meantime can only be removed from the skin with difficulty



2412 November 10 1952 — 2412 a November 10 1952 — 2412 b March 30 1953

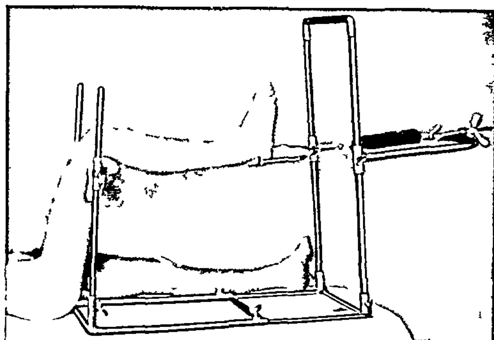
FIG 2412—Double fracture of the left lower leg bones with four tibial fragments in a 63 year old pensioner who was hit from the front and knocked down by an automobile The most distal tibial fragment has been displaced medially and dorsally by its full shaft diameter Anterior wedge shaped fragment (bending wedge) broken off at the proximal fracture site of the fibula Reduction with calcaneus pin traction in the short screw traction apparatus A wire was drilled through the middle fracture site to fasten the proximal fragments to the proximal vertical iron bars of the screw traction apparatus Distraction (i e separation in the long axis) of the proximal fracture sites was thereby avoided

FIG 2412 a—Check roentgenograms of the same patient following reduction Good apposition of the fragments has been achieved Further treatment by pin traction weighted with 3 kg lateral pad at the distal fracture site Three weeks later a long leg walking cast was applied for another 9 weeks

FIG 2412 b Same case five months later Bony union in good position The most proximal and the most distal fragments are in line Oblique position of the two intermediate fragments External shape of the lower leg straight Slight demineralization

Removing Plaster Particles with the Vacuum Cleaner If plaster particles have fallen into the plaster cast they may be removed with a swab stick or a forceps but a vacuum cleaner will do this much more quickly and better

Application of a Walking Stirrup If the position of the fragments is satisfactory a walking stirrup (figs 2655—2658) is applied At present we



October 17 1931

Fig 2410—Leg with fracture of the tibia and fibula positioned on the screw traction apparatus Calcaneus pin traction of 5 Kg A spring scale is inserted between the calcaneus pin and the hook of the screw

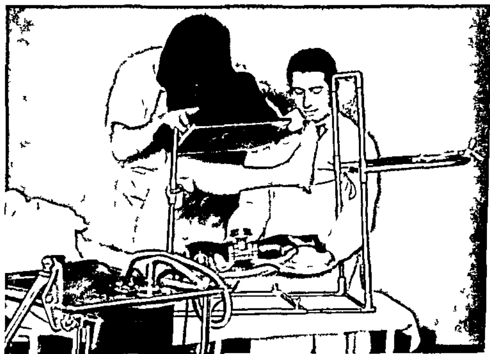
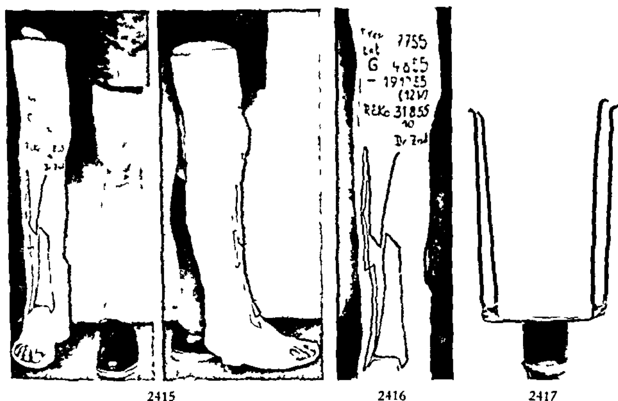


Fig 2411—The position of the fragments is examined with a portable Philips roentgen apparatus At present we use a Siemens roentgen tube (M N/fig 804 805) and an operation fluoroscope of Heinz Braun (M N fig 107)

no longer use the stirrup made of flat iron (Vol I/fig 143), as it must be removed for the lateral roentgenogram but a stirrup with four strong wires (fig 2417)

Marking the Cast The pre reduction roentgenogram is sketched over the fracture site The day of the injury, of the application of the cast, and of the prospective removal of the cast, the date and hour of the future check roentgenograms, and the name of the doctor are inscribed distal to the knee (figs 2415, 2416)



2415 2416 2417

FIG 2415 – Anterior and lateral view of a long leg walking cast in a case of fracture of the shafts of the tibia and fibula with correct inscription and roentgen sketch

FIG 2416 Detail of the full leg walking cast of fig 2415 The day month and year of the accident the reduction the continuous traction the application as well as the prospective removal of the walking cast (in brackets the number of weeks from accident until the removal of the cast) and the date and hour of the next roentgen check as well as the name of the surgeon are inscribed The anteroposterior pre reduction roentgenogram is sketched in full size over the fracture site

FIG 2417 Walking stirrup after Zehetgruber Steel sheet to which two pairs of strong wires are welded covered by a rubber cap

Checking the Roentgenograms the Cast, the Roentgen Sketch and the Inscription on the Cast If a young doctor has applied the cast a senior surgeon will examine the cast and sign it after having checked whether the last roentgenograms show satisfactory position in both planes, whether the cast has been well applied, the foot being neither in drop foot nor calcaneus position, whether the edges of the cast have not been cut out too little or too much at the toes, whether the toes have been cleansed well and show a sufficient range of active dorsiflexion, whether the roentgen sketch corresponds with the



2413 December 1 1939 — 2413 a December 2 1939

Fig 2413—Oblique bending fracture of the middle thirds of the tibia and fibula in a 29 year old passenger in an automobile collision The distal fragment of the tibia is displaced laterally half the width of its shaft Shortening of 10 mm Recurvation of 10° Reduction by manual traction at the calcaneus pin was followed by continuous traction with 3 kg on a lower leg splint for four weeks Long leg walking cast for another six weeks

Fig 2413 a—Same case one day later Still shortening of 5 mm and lateral displacement by the width of the cortex This is the optimal position for speedy callus formation Axes in both planes straight



2414 February 9 1940 — 2414 a February 23 1952

Fig 2414—Same case ten weeks later on removal of the cast Axis in both planes satisfactory Shortening of 5 mm Fracture cleft bridged by callus Slight demineralization of ankle region

Fig 2414 a—Same case thirteen years later Normal extern and color free active motion of all joints bony union of site no



2422 January 3 1947 — 2423 January 17, 1947 — 2424 July 18 1947 — 2425 December 6 1948

Fig 2422—Double fracture of the right tibia and fracture of the right fibula in a 44 year old asthenic unskilled worker who was buried under debris The middle third of the tibia is broken out Bending wedges at the medial sides of both fracture sites Total shortening of 12 mm

Fig 2423—Same case 14 days later Continuous calcaneus pin traction weighted with 3 kg Diastasis of 3 to 5 mm at the distal fracture site of the tibia of 5 mm at the proximal site The traction weight was therefore reduced to 2 kg and to 1 kg one week later A long leg walking cast was applied after five weeks

Fig 2424—Same case on removal of the cast after six and a half months There is only a small callus bridge at the lateral side of the distal fracture site otherwise the fracture cleft is still open The proximal fracture site is bridged by periosteal callus Severe demineralization especially of the ankle region

Fig 2425—Same case two years later The proximal fracture site of the tibia shows bony union the distal site shows a firm non union with occluded medullary spaces and sclerosed fracture ends Calcium content almost normal In this case a check roentgenogram on the second day was not obtained Therefore the gap between the distal fragments was not discovered until after two weeks If an osteotomy of the fibula or an onlay bone graft at the tibia had been performed in this patient in time bony union would have probably occurred This is the other case of non union among our 1130 closed fractures of the shafts of the lower leg bones Figs 2418—2425 are taken from a paper by Ender Krotschek and Jahna (to be published)

day The following weeks one kilometer should be added to the daily distance each week *as long as this elicits no pain* Moreover, the patients should raise the leg to the horizontal several times to strengthen the thigh muscles The whole body should also be exercised Self-employed persons usually take up their occupation one or two weeks after application of the walking cast

Roentgen Check Two weeks after application of the walking cast roentgenograms are made in both main planes If necessary they are repeated every other week

Shortening the Full Leg Walking Plaster Formerly in fractures of the lower halves of the tibia and fibula we removed the upper part of the cast in the seventh week and left the knee free But as angulation occurred in some



2418 April 20 1944 · 2419 May 17 1944 · 2420 August 23 1944 · 2421 February 28 1947

FIG 2418—Oblique bending fracture of the right tibia and fibula with serrate fracture surfaces Sustained by a 50 year old machinist who was hit and knocked down by an automobile *from behind* *The distal fragment is displaced laterally by the full width of the tibial shaft* and dorsally by half its width Posterior flexion wedge at the fibula Shortening of 7 mm Continuous calcaneus traction with 3 kg for 11 days then with 4 kg

FIG 2419—Same case 33 days later after an attempt to bring the fragments into apposition in the screw traction apparatus under anesthesia This is no longer possible Diastasis in the ankle joint

FIG 2420—Same case four months later at removal of the cast The distal fragment of the tibia is displaced laterally and posteriorly by half the diameter of its shaft A 10 by 10 mm callus bridge at the posterolateral side of the tibia is not yet in firm contact with the distal fragment Shortening of 5 mm Fracture appears clinically firm Medium degree of demineralization

FIG 2421—Same case three years later Varus of 5° Fatigue fracture through the callus bridge with beginning sclerosis of the fracture ends Springy resistance of the fracture on clinical examination Established non union of the tibia two years later This fracture would probably have consolidated if it had been immobilized in plaster for another 2 or 3 months These fractures should be brought into exact apposition in the screw traction apparatus on the first day Further treatment should consist in a four weeks continuous traction followed by a long leg walking cast for eight weeks This is one of the two cases of non union observed in our 1130 cases of closed fractures of the shafts of the tibia and the fibula After comminution performed two years later the fracture united after four months immobilization

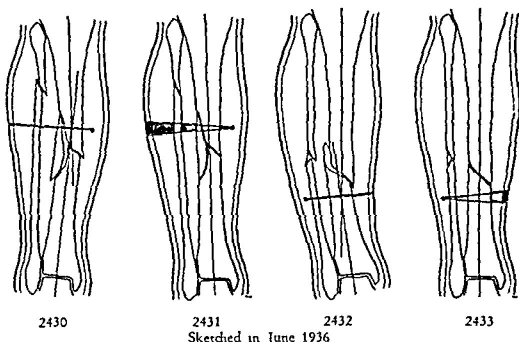
primary roentgenogram whether the inscription on the cast is correct whether the duration of immobilization has not been planned for too long and, by all means, not for too short a period

Exercises with the Cast On When the cast has hardened after a few hours the patient can start walking with the aid of two walkers, and on the following day with two canes Juveniles can often walk in the room without a cane as soon as one week later, in aged patients this will take slightly longer

If the position of the fragments is satisfactory, and there has never been distraction walking will be painless within a few days The patients should walk at least one kilometer daily at one time but distributed over the whole

Functional Result after Removal of the Full Leg Walking Cast If the position of the fragments is good and if the patients have walked a good deal with the cast, there is, as a rule, but little muscle atrophy and little decalcification of the bones The ankle joint can often be moved through half its range and the knee joint through 20° to 40° After one week it can usually be flexed to 90°, its full range of motion is usually achieved within a short period of time

Application of an Unna's Paste Boot and an Elastic Bandage In adults edema follows every fracture of the tibia and fibula Edema can be avoided if an Unna's paste dressing is applied immediately after removal of the cast which



Sketched in June 1936

Figs 2430 2431 —Correction of angulation shortening and apparent lateral displacement by making a cut with a saw round two thirds of the cast at the concave side of the angle The cut is then opened to a wedge The fulcrum lies in contradistinction to figs 2426 2427 on the convex side of the angle The cut lies at the level of the intersection of the axes of the main fragments and not necessarily at the level of the fracture Lengthening and correction of the apparent lateral displacement are produced Cutting the plaster and opening the cut to a wedge is an easy method which can be performed with perfect control and which causes no decubital ulcer It is superior to excision of a plaster wedge (figs 2426—2429) a method we have given up completely In correction of valgus shortening is overcome to a lesser degree as compared with a correction of varus (figs 2430 2432) where the tibial fragments are further away from the fulcrum than in valgus (after Kromer and Heuritsch)

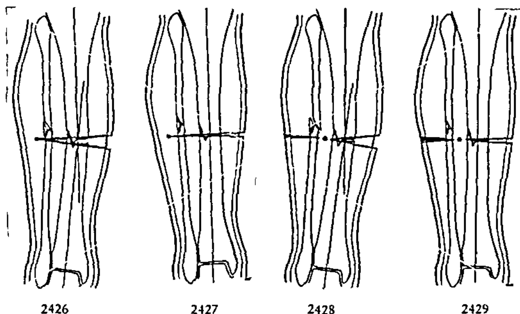
extends from the webs of the toes up to the knee (see "Verbandlehre," pp 74—86) and if an elastic bandage is wound round the knee during the day time The patient should not take a bath after removal of the cast since the leg would become swollen It suffices to wash off the leg

The paste dressing usually becomes loose after one week and should then be changed Later on this Unna's paste boot is renewed every 2 to 4 weeks Juveniles usually wear this dressing through 3 to 6 weeks, old people and those with varicose veins 3 to 5 months They usually take up work with this dressing After some weeks an elastic stocking may be worn instead of the Unna's paste dressing

cases, we now no longer shorten the cast in spite of the patient's repeated requests There is no reason to leave the knee free earlier, as we have found that only 5 18% of all patients developed a slight limitation of knee motion

Changing the Cast If the roentgen check shows angulation of the fragments, or if the plaster cast has become damaged or broken, it must be changed and re-applied as described on pages 1724, 1725

Examining the Firmness of the Fracture and Roentgen Check When Changing the Plaster If a plaster cast is changed, the firmness of the fracture should be checked and a check roentgenogram made prior to application of the



2426 2427 2428 2429
Sketched in June 1936

Figs 2426 2427 —Excision of a wedge of plaster to correct valgus angulation The wedge extends with its ends beyond half the circumference of the cast In contradistinction to figs 2428—2431 the fulcrum lies on the concave side of the angle at the level of the intersection of the axes of the main fragments Correction of the angulation causes shortening We used to apply this method of excision of a wedge when there was a gap between the fracture ends (after Kromer and Heuritsch [1])

Figs 2428 2429 —Correction of valgus by excising a wedge of plaster medially and cutting the plaster laterally The fulcrum lies in the middle of the cast Correction of the angulation thus causes neither shortening nor lengthening We have given up excision of a plaster wedge because of the danger of pinching the skin

new cast in order to determine the progress of callus formation A new roentgenogram should be made after application of the new plaster

Duration of Immobilization In torsion fractures we remove the cast in ten weeks, in flexion fractures in twelve weeks after the injury and examine the bones by bending and impaction for their firmness and tenderness If distraction has never existed and if the patients have walked a good deal with the cast on, the fracture will as a rule, be firm and weight bearing will be possible Some torsion fractures probably consolidate as soon as after 6 to 8 weeks It is, however, more expedient to leave the plaster on through ten weeks

1 Kromer and Heuritsch Ausgleich von Achsenknickungen Der Chirurg 8 850—853 1936

Questions We Should Ask Ourselves in Order to Avoid Failures in Treating Closed Fractures of the Tibia and Fibula in a Long Leg Walking Cast

1 Have I had the material prepared as quoted on page 1515 and described on page 1724 and have I checked them for completeness and quality?
2 Has a helper firmly held the foot at the dorsum and above the ankles on removal of the rotating stirrup?
3 Has the foot been held by a helper when the pin was cleaned?
4 Has the foot been held firmly when the pin was extracted?



2435 November 20 1931 2436 December 23 1931

Fig 2435 —Same case nine weeks later Slight antecurvature Callus has formed laterally The fracture cleft can still be seen medially

Fig 2436 —Same case five weeks later i e fourteen weeks after the injury Callus has also formed medially the lateral callus has become stronger There is a medially open angle between the fragments 10° varus The cast should have remained for 12 weeks since transverse fractures never unite within 9 weeks The angulation was corrected by bending the lower leg over a wooden wedge

5 Have I dressed the pin holes with a 2×2 cm swab with balsam of Peru and glued it on with Mastisol?
6 Have I positioned the patient as shown in figure 2175?
7 Has a helper supported the fracture site with one hand and held the patient s big toe with the other hand so that the inner side of the foot is vertical and the foot is neither rotated nor in a drop foot position?
8 Have I daubed the skin of the middle or upper third of the thigh with mastisol skin adherent and placed the 5×70 cm flannel strip (cut in at one edge) wrinkle free in such a way that its ends overlap at the lateral and not the anterior side of the thigh?

Treatment of Knee Joint Effusion Effusion of the knee joint develops in some cases It will disappear after a few days or after 1 or 2 weeks if walking has been restricted for some days, sponge compression has been carried out and the knee has not been irritated by massage, passive movements or excessive heat

Exercises after Removal of the Cast Normal use of the leg i e, walking, is the best exercise if it causes no pain When the knee joint can be flexed beyond the right angle, the ankle joint can be exercised by an upward and downward movement of the ankle, i e by vigorously raising and pressing down the heel ten times in the seated position Standing and moving on tiptoe



2434 September 17 1931

Fig 2434—Bending fracture of the tibia and fibula with a small laterally displaced bending wedge Since the fibular fragments have not been displaced a gap has formed between the tibial fragments Reduced under local anesthesia by bending the distal fragment medially Application of a long leg cast for 2 weeks followed by a long leg walking cast for another 6 weeks

should also be practiced This can usually be carried out after 3 or 4 weeks Light sports, including swimming should follow afterwards

Massage and passive movements are never carried out as massage can only be performed after removal of the Unna s paste boot This, however, causes the swelling which the massage is meant to combat Energetic passive movements are always harmful Joint effusions and massive swelling will ensue (see figs 2390, 2391 and the case history on page 1714)

Check Roentgenogram at the End of Treatment Prior to discharge from treatment new roentgenograms should be made to recognize in time disturbances in the callus formation or angulation (fig 2436)

33 Have I taken new roentgenograms without the cast when changing the cast?
34 Have I taken roentgenograms in both planes after application of a new cast?
35 Have I continued immobilization 10 weeks in torsion fractures and 12 weeks in flexion fractures?
36 Have I tested the firmness of the fracture and the mobility of the joints after removal of the long leg walking cast?
37 Have all findings been immediately entered in the case history?
38 Has the patient refrained from bathing to avoid edema of the leg?
39 Has an Unna's paste boot been applied from the webs of the toes up to the knee (see 'Verbandlehre,' pp 74—86)?
40 Has an elastic bandage been wound round the knee to be worn during the daytime?
41 Has the Unna's paste boot been changed, if it has become loose, i e, usually after one week?
42 Has a light compression bandage been applied in the case of knee-joint effusion?
43 Have I refrained from massage, passive motion and overheating in effusion of the knee joint?
44 Has the patient exercised and walked as long as this does not cause pain?
45 Has the ankle joint been exercised by moving the heel upwards and downwards while the toes remain on the floor?
46 Have *massage, passive motion, overheating and all painful exercises* been omitted?
47 Have new roentgenograms been made at the end of treatment to detect, in time, disturbances of callus formation and angulation (fig 2436)?

Treatment of the "Half" Torsion Fractures of the Lower Leg

Ender coined the term 'half torsion fracture' While the tip of the proximal fragment lies *medial* (figs 2373 d, e) in the common external rotation fractures, and lies *lateral* (figs 2373 f) in the rare internal rotation fractures, it lies half way between the medial and lateral side of the tibia in the case of a "half" torsion fracture (figs 2373 g, 2379—2382, 2464—2469) This type of fracture is of particular importance because displacement of the fragments, when in continuous traction, may increase to a full shaft's width if the foot is rotated inwards prior to correction of the shortening As the fracture surfaces no longer face each other, callus formation will be severely delayed Only the cortices of the fragments are in contact

Manual Reduction In fresh cases, manual reduction is attempted on the lower leg splint under local anesthesia by traction at the calcaneus pin and by subsequent internal rotation If the foot is rotated inwards *prior* to correction of the shortening lateral displacement of the distal tibial fragment by its full shaft's width will often occur

Reduction in the Screw Traction Apparatus If manual reduction fails, the screw traction apparatus (figs 2410 2411) should be used to exert the necessary

9 Have I positioned the dorsal plaster splint in a way that it does not reach beyond the edge of the flannel strip and will not cut into the skin?
10 Have I turned back the flannel strip before the application of the last plaster bandage to provide for a smooth upper edge of the cast which will not cut in to the skin?
11 Have I carried out fluoroscopy of the lower leg after application of the cast?
12 Have I bent straight the lower leg when the cast is still soft if fluoroscopy showed angulation?
13 Have I made roentgenograms in both planes?
14 Have I removed the cast and applied a new one if the roentgenograms show angulation of more than 15°?
15 Have I wedged the cast in angulation of 3° to 15°?
16 Have I only cut the cast in a patient who is not under local or general anesthesia?
17 Have I as a rule refrained from wedging in view of frequent decubital sores and ulcers?
18 Have I carried out a fluoroscopy if I have wedged the cast and inserted a piece of cork?
19 Have I made roentgenograms in both planes after fluoroscopy?
20 Have I, in satisfactory position of the fragments, filled the wedge shaped gap with a carefully cut piece of cellulose?
21 Have I reinforced the wedged cast by a plaster splint and a circular plaster bandage?
22 Have I when trimming the cast, left the plaster medial to the big toe and lateral to the fifth toe so that the toe plate remains strong enough?
23 Have I cut the edges of the cast so that the cast extends to the webs of the toes, i e , to allow for dorsiflexion of the toes as well as to avoid edema and decubital sores and ulcers?
24 Have I exposed the extensor side of the basal phalanx of the big toe?
25 Have the patient s toes been cleansed before he has left the plaster room?
26 Has a vacuum cleaner been used to clear the cast of plaster particles?
27 Has a walking stirrup with four vertical wires (fig *2417*) been applied which need not be removed for lateral roentgenograms?
28 Has the pre-reduction roentgenogram been sketched over the fracture site and have the dates of the accident reduction, traction and application of the long leg cast, as well as date and hour of intended check roentgenogram and removal of the cast and the doctor s name been recorded on the cast (fig 2416)?
29 Has the cast, the roentgen sketch and the marking of the cast been checked by a senior surgeon?
30 Has the patient walked after the cast has hardened?
31 Has the cast remained on until the fracture has united and not been shortened below the knee after a few weeks?
32 Have I attempted to bend the fracture in order to check the firmness of the union on changing the plaster?

traction In open double fractures with lateral displacement by a full shaft's diameter the fragments are apposed in the open wound by means of single-pronged bone hooks

Immobilization in Closed Double Fractures After reduction has been carried out manually or in the screw traction apparatus, treatment is continued by longitudinal traction weighted with 2 kg If necessary a lateral pad or



2437 September 19 1931 — 2438 January 8 1932

Fig 2437 —*Open* double fracture of the lower leg bones with varus of 20° and recurvation of 20° between the distal fragments

Fig 2438 – Same case 16 weeks later The wound was carefully excised and the skin and only the skin was sutured after insertion of a drain Reduction in the screw traction apparatus by traction on a calcaneus pin A pin was then driven through the upper end of the tibia A cast was applied which was *split immediately* and fenestrated over the wound area Wound healing was uneventful When the cast and the pins were removed after 10 weeks the upper fracture still had a spring mobility An Unna's paste boot and a plaster cylinder were applied Four weeks later all fragments were firmly united Good alignment between the proximal and the distal fragment Oblique position of the intermediate fragment External shape of the lower leg straight Compare with figs 2038—2044 of Vol II At present we treat such fractures without transfixion in continuous traction for 4 weeks and in a full leg walking cast for another 8 weeks

lateral traction can be added (see pp 1704—1724 and fig 2375) Four weeks later a full leg walking cast is applied

Immobilization in Open Double Fractures After insertion of the calcaneus pin the wound is carefully excised The fragments, displaced by a full shaft's diameter, are apposed with single pronged hooks under longitudinal traction

amount of longitudinal traction Also in this case the shortening must be corrected *prior* to internal rotation of the foot

Immobilization by Continuous Traction After reduction and positioning the leg on a lower leg splint a well lined pad (after Bartmann) is applied at the medial side of the fracture (fig 2375) In continuous traction, weighted with 2 to 3 Kg, the fragments can usually be kept in satisfactory position

Immobilization with Intramedullary Wires If the fragments cannot be kept in satisfactory position by continuous traction, one to three medullary wires are introduced into the tibia (figs 2464—2466) as described on pages 1752—1757 Further treatment is the same as in ordinary torsion fractures, i e, continuous traction for three weeks and a full leg walking cast for another seven weeks (see pp 1704—1737)

Open Reduction and Immobilization by a Loose Wire Loop From 1949 to 1954 we exposed the fragments in some cases, performed an open reduction and fixed the fracture ends by means of a *loose* wire loop (figs 2467—2469) At present we prefer closed insertion of medullary wires as this is a simple method and has proved more successful

Treatment of Double Fractures of the Lower Leg

Severe complications may result from anatomic reposition and osteo synthesis of the fragments in double fractures With or without occurrence of infection delayed callus formation or non union may ensue Sequestra may become cast off in some cases Fracture healing may then extend over a number of years (figs 2497—2500)

If one keeps in mind that it is important to strive for adequate shortening, bony union in good position and good function can, as a rule, be achieved in three to four months One should also be aware of the fact that lateral displacement by half of the shaft s width in tibial fractures, and by full shaft s width in fractures of the femoral or the humeral shafts, are of no cosmetic or functional significance, if there is no considerable shortening no angulation and no rotation (Vol II/figs 2038—2044) In double fractures, straight axes need only be achieved between the proximal and the distal fragment, whereas the intermediate fragment may lie obliquely (figs 2437, 2438 2493—2496, 2501—2504)

Reduction If the fragments are laterally displaced by one half or two thirds of the shaft s width and are angulated, it suffices to bend the fractures straight manually, after insertion of the calcaneus pin and to continue with traction If, in a closed fracture there is lateral displacement by a full width of the shaft at one of two or three sites of fracture, the fragments must be brought in apposition in the screw traction apparatus Fragments which are only slightly displaced must then be held firmly lest they be drawn apart If, for example, displacement by the full width of the shaft occurred at the distal fracture site as in figure 2412 a wire is drilled through the adjacent proximal fragment and fixed to the screw traction apparatus Thus, calcaneus pin traction acts at the distal fracture site only If displacement by a full shaft s width with shortening occurred at the proximal fracture site as in figure 2501, a wire should be drilled through the intermediate fragment for

4 Have I avoided excessive weight for longitudinal traction, i e, starting with not more than 2 kg in closed and not more than 4 kg in open fractures which have been immobilized in plaster in order to avoid distraction (figs 2422—2425)?
5 Have I obtained a roentgenogram on the second day to rule out a gap in the long axis of the bone (longitudinal diastasis, fig 2423)?
6 Have I at once reduced the traction weight if longitudinal diastasis has been detected?
7 Have I refrained from osteosynthesis to avoid non union (figs 2422—2425) and infection (figs 2497—2500)?

ISOLATED FRACTURE OF THE TIBIAL SHAFT

Origin Isolated fracture of the tibial shaft often occurs from direct force which is not sufficiently violent to fracture both bones It may also result from indirect force, namely, by rotation This origin is common in children

Types of Fracture Direct violence usually causes transverse fractures (figs 2439—2446), indirect violence causes torsion fractures of the distal third

Transverse fractures frequently show no displacement (fig 2443), in some cases, however, there is lateral displacement by one half or almost the entire width of the shaft (fig 2439) Shortening may originate in the case of subluxation in either the proximal or distal tibiofibular joint, similar to the isolated fracture of the radius (Vol I/figs 988—1031) As the distal tibiofibular joint has much stronger ligaments than the proximal one, the head of the fibula glides upwards in many cases This may even cause paralysis of the peroneal nerve Regele[1] has reported on such a case

Treatment In fracture of the tibia without displacement (fig 2443) the leg is placed on a gutter splint (see page 1703) or encased up to the mid-thigh in a plaster cast which is split immediately throughout its full length (see pp 1724, 1725) In children we apply a plaster cast (see p 1743) or pin traction (see p 1704) the latter being a very simple and safe method if there is an opportunity to hospitalize the patient After application of the cast the check roentgenogram often shows the typical angulations, namely, varus and recurvation (fig 2444) These displacements can usually be avoided if correct pressure and counterpressure are exerted when applying the cast The lower leg should be firmly held by one hand close above the fracture site exerting pressure from the posterolateral side The other hand should press upon the anteromedial side of the ankle region thus bringing the distal fragment in line with the proximal fragment If the swelling of the lower leg has subsided after 5 to 8 days a long leg walking cast is applied which will be removed 8 to 10 weeks after the injury Roentgenograms in both planes should be obtained before and after application of the cast

A fracture with displacement is reduced under local anesthesia manually after insertion of a calcaneus pin, if this fails, in the screw traction apparatus

[1] Regele Wirkt bei isolierten Bruchen des Schienbeines das stehengebliebene Wadenbein immer als absolut verlaßliche Stutze gegen die Verkurzung? Zentralbl Chir *61* 550—553 1934

After insertion of a drain and suture of the skin the patient is placed on a screw traction apparatus and under calcaneus pin traction of about 5—6 Kg, a full leg cast is applied which is split immediately throughout its full length The leg is then placed on an oblique splint and continuous traction of 3—4 Kg (figs 2350, 2350 a) is exerted Placing the patient on the screw traction apparatus, application of the cast and check roentgenograms are performed as in a case of bicondylar overextension fracture of the upper end of the tibia (see pp 1666—1677) Four weeks later, at the earliest, a long leg walking cast is applied In case of disturbed wound healing the cast is not applied until the wounds have sufficiently closed

First Roentgen Check On the second or third day, at the latest roentgenograms are made to confirm that no gap in the long axis has formed at either fracture site If such distraction has been overlooked for even as little as two weeks, delayed callus formation and non-union may ensue as in figures 2422—2425

Second Roentgen Check This is made after one week Further check roentgenograms are made every other week, or even more often if complications set in

Further Treatment in the Full Leg Walking Cast In closed double fractures a long leg walking cast (see pp 1724 1725) is applied four weeks after the accident In open double fractures the cast is applied when the wounds have closed or have, at least, healed sufficently

Duration of Immobilization in the Long Leg Walking Cast If double fractures of the lower leg bones have been adequately reduced and if distraction has never occurred firm union and good weight carrying capacity are as a rule, achieved in twelve weeks (figs 2437, 2438 2501—2504)

Avoidance of Operative Treatment in Double Fractures If the fragments are reduced by open operation and wire loops (figs 2497—2500) or longitudinal wire sutures are applied or a medullary nail is inserted (M N /figs 856—863) there will often be delayed callus formation non-union, or infection with sequestra being cast off The period of fracture healing may then extend over years and the end-result will be a bad leg forever

Questions We Should Ask Ourselves in Order to Avoid Failures in the Treatment of Double Fractures of the Tibia and Fibula

The following questions should be asked in addition to those given for the treatment of ordinary fractures of the tibia and fibula (pp 1715, 1718 1735)

1 Have I apposed the fracture ends in the screw traction apparatus if in closed transverse fractures, there was displacement by a full shaft s width and shortening?
2 Have I when carrying out reduction in the screw traction apparatus protected the fragments which were but slightly displaced by means of wire traction in order to avoid distraction (fig 2412 a)?
3 Have I after excision of the wound apposed the fracture ends with single pronged bone hooks if in an open transverse fracture there was displacement by the full width of the shaft and shortening?

Questions We Should Ask Ourselves in Order to Avoid Failures in the Treatment of Isolated Fracture of the Tibial Shaft

1 Have I reduced lateral displacement manually or in the screw traction apparatus?
2 Have I corrected varus and recurvation by applying pressure on the posterolateral side close above the fracture site and counterpressure on the anteromedial side of the ankle region?
3 Have I omitted all attempts to correct a deformity by wedging the cast as this would cause decubitus ulcers over the fibula?

ISOLATED FRACTURE OF THE FIBULAR SHAFT

Origin Isolated fracture of the fibular shaft occurs but rarely It is always caused by direct violence

Fibular fractures which are associated with severe injuries of the ankle joint (figs 2633—2640, 2721, 2772) are not considered here as they are of little importance in view of the severe main injury

Treatment When the swelling has subsided an Unna s paste dressing is applied from the webs of the toes up to the knee (see pp 74—86 of the "Verbandslehre")

FRACTURES OF THE SHAFTS OF THE TIBIA AND FIBULA IN CHILDREN AND JUVENILES

In children the same types of fracture are found as in adults Torsion fractures of the tibia alone are common but are rarely combined with those of the fibula Transverse fractures with lateral displacement by the full width of the shaft with shortening may also occur

Treatment In *transverse fractures with displacement by a full shaft s width and with shortening* reduction is performed manually or, if this fails, in the screw traction apparatus (see p 1710 and fig 2410) Traction treatment follows until the swelling of the lower leg has subsided after 8 to 10 days A full leg cast is then applied (see pages 1724, 1725) for eight weeks

In the *frequent cases of isolated torsion fractures of the* tibia we usually apply a long leg cast on the first day, the cast must be immediately split throughout its full length When applying the cast care should be taken to correct varus and recurvation as described on page 1741 A short leg cast will usually not suffice to avoid re-angulation

Duration of Immobilization In children under six years of age union of torsion fractures usually takes 4 weeks, in older children it takes 5 to 6 weeks Transverse fractures with displacement by a full shaft s width and shortening should be immobilized for 8 weeks to avoid re-angulation

Subsequent Treatment Since in children marked swelling is uncommon after removal of the cast, it is rarely necessary to apply an Unna s paste boot Without any further treatment children can usually walk normally within a short time

(see p 1710 and fig 2410) and is kept in traction until the swelling of the lower leg has subsided It is expedient to apply the traction eccentrically on the medial side to correct the varus (Vol II/fig 1993) and to have the foot suspension low enough to avoid recurvation On the second day roentgeno grams should obtained After 8 to 10 days a long leg walking cast (see pp 1724, 1725) should be applied which remain until 8 to 10 weeks after the accident

Osteotomy and Osteoclasia of the Fibula In the rare cases where angulation cannot be corrected by the above methods the fibula may be fractured either by open osteotomy or closed by means of Phelps Gocht s osteoclast (Vol I/fig 138) Then, angulation can easily be abolished (figs 2445, 2446) In about 250 fresh isolated fractures of the tibial shaft we have performed open osteotomy of the fibula only once, namely, in the patient shown in figs 2443—2446, and closed osteoclasia in six cases Excision of a piece of the fibula, as has often been suggested even for fresh cases, is not necessary If, in cases of longer standing, the tibia can no longer be bent straight, osteoclasia in juveniles and osteotomy in adults should not be delayed for too long

Correction of Angulation by Wedging the Cast In isolated fractures of the tibial shafts wedging of the cast should never be attempted as it leads to decubital ulcers over the fibula

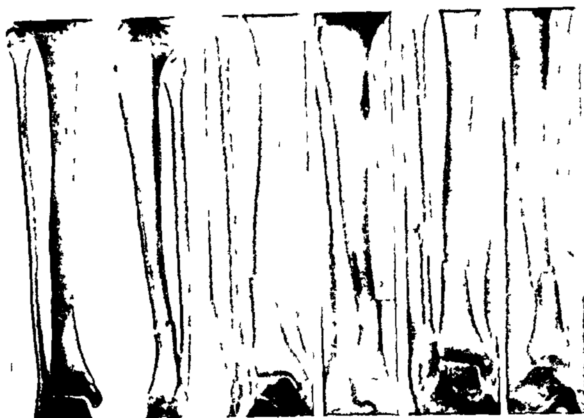
Every fracture is followed by absorption of the fracture stumps of from 1 to 3 mm This is harmless as long as the fracture ends are approximated by muscle pull and are not hindered by excessive continuous traction If only one bone is fractured in the lower leg or the forearm, the uninjured bone prevents the approximation of the absorbed fracture ends, if the joints between these bones remain stable In isolated fractures of the tibial or forearm shafts with shortening due to subluxation of a fragment the period necessary for healing after reduction is comparatively short (Vol I/figs 1002—1031) whereas in fractures without shortening bony union may require one year (figs 2439—2442 Vol I/figs 970—973) This is particularly striking in fracture of the ulna with dislocation of the radius when the radius has been reduced and acts as a strut keeping the ulnar fragments apart (Vol I/ figs 864—871)

Roentgen Controls As angulation often recurs in these fractures check roentgenograms in both planes should be obtained every other week

Exercises are carried out as in fractures of the shafts of the tibia and fibula (see page 1718)

Duration of Immobilization In fractures which originally had a shortening and in cases with osteotomy of the fibula the cast may be removed after 2 months If the fibula has not been broken and if the fracture space is clearly visible, as in figure 2440 the cast should remain for 10 to 12 weeks

After this period it is not necessary to drill the fracture or to give callus forming remedies as firm bony union with continuity of bone structure will develop by itself in the course of 8 to 12 months The patients are almost asymptomatic in the meantime (see fig 2441)



2443 August 29 1934 2444 August 29 1934 2445 September 7 1934



2446 November 12 1934

Fig 2443 —Isolated transverse fracture of the lower third of the tibia without displacement Sustained by an 18 year old gardener who was knocked off his bicycle by an automobile

Fig 2444 —Same case after application of the cast Varus and recurvation of 10° each If adequate posterolateral pressure is exerted against varus and recurvation these angulations can usually be avoided

Fig 2445 —Same case after open osteotomy of the fibula Good alignment in both planes

Fig 2446 —Same case after ten weeks Bony union with varus of 7° Free range of active motion of all joints The man resumed work



2439 December 3 1936 2440 February 26 1937

FIG 2439—Isolated transverse fracture through the mid shaft of the tibia sustained by a 42 year old man who fell from an automobile Lateral displacement and valgus of 5° Manual reduction Long leg cast which was immediately split for 2 weeks followed by a long leg walking cast for 6 weeks

FIG 2440—Same case after 3 months Good position of fragments Callus has formed posteriorly and laterally Fracture clinically firm



2441 May 15 1937 2442 December 6 1937

FIG 2441—Same case after 5½ months Fracture line has become narrower looks like non union with sclerosed bone ends Patient walks almost painlessly

FIG 2442—Same case after 12 months Fracture gap closed Asymptomatic Compare with Vol I/figs 962—973

but where infection (figs 2477—2482) and non union (figs 2470—2476) had followed the operation and treatment had extended over years

Torsion fractures of the tibia were especially striking since the long fracture surfaces healed well while transverse non union (figs 2470—2473) developed between the two wire loops or metal bands

Healing is extraordinarily delayed if infection occurs In the case shown in figures 2497—2500 the patient was on sick-leave for two and a half years

After operation of transverse fractures no gap must be left between the fracture ends as in figure 2477, nor must a flexion wedge be removed because angulation will follow in spite of a plate as shown in figure 2477

Operative treatment is not necessary in fresh fractures of the tibia and fibula as even the severest fresh closed fractures of the tibia and fibula can be reduced in the screw traction apparatus and can be kept in good position by continuous traction

Cornioley's[1] statistics show that end-results after operative treatment are unfavorable in general He reports on 50 operative cases of *closed* fractures of tibia and fibula Of these 16 (32%) showed good results, 30 (60%) healed with permanent disability, 23 (46%) had a shortening of 1 to 6 cm, 25 (50%) had displacements of the fragments, 13 (26%) had stiffened or ankylosed knee or ankle joints, 14 (28%) had hypertrophic or painful callus, 25 (50%) had muscle atrophy, in 7 (14%) infection occurred If we compare our results of *open* fractures of tibia and fibula as published in Ehalt's[2, 3] book or observed by Zrubecky[4] in 1953 at his follow-up examination of our 461 open fractures of tibia and fibula, our end-results are much better

According to a report of Jager[5] in a series of eight closed fractures of tibia and fibula treated with Lane's plates and screws, infection occurred in four cases One of these patients had to have an amputation, another suffered infection of the knee joint Of these eight cases only one, in whom the plate was removed after 14 days, showed a good end-result

Transfixion by Two Pins or Two Wires in Closed Fractures of the Shafts of the Tibia and Fibula

From 1929 to 1933 we used the transfixion method (plaster cast and two transfixion pins or wires) in 65 closed and 36 open fractures of the shafts of tibia and fibula Since every transfixion is difficult of execution and rather time-consuming, and since infection of the proximal pin sites occurred in 15 cases necessitating sequestrectomy in three cases, we gave up this method Infection occured because we applied casts only up to the knee and let the patients walk If the knee is included in the cast and the patients kept in bed with a long leg cast, infection of the pin sites can probably be avoided As this method is still used in some hospitals I shall describe it

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[1] Cornioley Osteosynthese des os longs Paris Doin 1931

[2] Ehalt W Behandlung und Behandlungsergebnisse bei offenen Bruchen der langen Rohrenknochen Wien Maudrich 1938

[3] Ehalt W Tratamiento de las fracturas abiertas Barcelona Labor, 1940

[4] Zrubecky 54 Heft z Unfallheilkunde 1956

[5] Jager Schweiz Ztschr f Unfallmed Nr 3 1931

OPERATIVE TREATMENT OF CLOSED FRACTURES OF THE SHAFTS OF THE TIBIA AND FIBULA

There are three different methods of operative treatment of fractures of the shafts of the tibia and fibula

1 Methods without exposure of the fracture site (transfixion)
2 Methods with indirect exposure of the fracture site (a) Closed medullary nailing, (b) Closed medullary wiring
3 Methods with direct exposure of the fracture site
(a) Open medullary nailing, (b) Open medullary wiring, (c) Loose wire loop or loose wire suture, (d) Firm wire loop or metal band (Putti, Parham), (e) Firm transverse or longitudinal wire suture, (f) Screw fixation, (g) Plate and screws

In Vol I/pp 213—235, I gave full details of the dangers associated with all methods of operative treatment The dangers are (1) Death from operative shock, (2) Disturbances through infection (3) Delayed callus formation and non union, (4) Disturbances through defective technique due to lack of proper instruments and equipment, (5) Damage from chemical and electrolytic action of foreign bodies

If death from shock is avoided by operating on suitable cases only and if danger from metal disturbances is kept at a minimum by using proper material and by good surgical technique, the danger of infection still remains in spite of all antibiotics According to my observations in many patients admitted after having been operated on in other hospitals, in compensation cases, and during many travels, infection has followed many cases of operative treatment of closed fractures of tibia and fibula even after 1945 when antibiotics were introduced Moreover, removal of the hematoma delays callus formation The greatest danger of most operative procedures is impeded approximation of the fracture ends so necessary for bony union Unless a shortening of at least 3 to 5 mm has already been achieved at the time of reduction, the danger of non-union lies in the transfixion method, in closed and open medullary nailing (M N /figs 430—441, 816—823), in firm cerclage with metal bands or wire (figs 2470—2476) in transverse and longitudinal wire sutures in screws, and in the use of plate and screws All these methods prevent — especially in transverse fractures — the bone ends from approaching when they have become shorter after absorption and superficial necrosis The only methods allowing approximation of the bone ends are the use of closed or open medullary wiring (figs 2458—2466) of a loose wire loop (figs 2467 —2469), and of a loose wire suture (fig 2512 a) Egger s slotted plates should be included in this group but I have no personal experience with them

Operative treatment of fresh closed fractures of the tibia and fibula is a tempting method as the tibia lies close under the skin and can easily be exposed Especially inviting are torsion fractures of the tibia as they can easily be brought in apposition and secured with wires metal bands or screws I have often been tempted to operate on such cases With few exceptions I have, however, refrained from operation since we have received patients time and again who had been operated on in other hospitals by expert surgeons

are covered with a little cellulose and included in the plaster The patient must not get up with a transfixion cast

Application of a Full Leg Walking Cast Five weeks after the accident the transfixion cast and the pins or wires are removed A long leg walking cast is then applied as described on pages 1724, 1725 The cast is removed 10 weeks after the accident in torsion fractures and 12 weeks after the accident in bending fractures Further treatment is the same as described on pages 1730—1734



2450 October 23 1931 2451 October 23 1931

Fig 2450—*Open* fracture of the tibia and fibula with valgus of 25° and antecurvature of 25° Shortening of 2 cm Lateral bending wedge Compare fig 2447

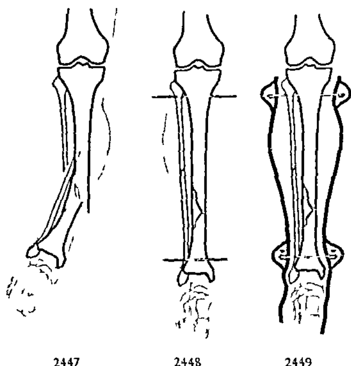
Fig 2451—Same after reduction in plaster Wound was excised and the skin alone sutured after insertion of a drain Reduction in the screw traction apparatus Two transfixion pins applied and a plaster cast which was split immediately A window cut out over the wound The wound healed without complication Patient received a long leg walking cast and began to walk three weeks after the accident Cast and transfixion pins removed after ten weeks Bony union in good position Two weeks later there was full active motion of the ankle joint Since 1933 we have no longer used transfixion as good position can also be maintained by a plaster cast and continuous calcaneus pin traction

The treatment in a transfixion cast, in my opinion, offers no advantages in closed fractures of the shafts of tibia and fibula since its application takes much time, and walking can be begun only after 5 weeks, while patients treated in continuous traction can get up as early as after 3 to 4 weeks Moreover, there is the danger of distraction and infection of the pin sites

For transfixion (plaster cast and two transfixion pins or wires) the same equipment, with a few exceptions, is needed as for treatment of a bicondylar fracture of the upper end of the tibia (see p 1666)

Correct Time for Application of the Transfixion Cast The cast may be applied on the first day or after swelling has subsided, i e, after 8 to 10 days In the latter case initial treatment consists of continuous traction as described on pages 1704—1716)

Reduction in the Screw Traction Apparatus For reduction, the patient is placed on the screw traction apparatus as described on pages 1667—1676



2447 2448 2449

Sketched in December 1931

FIG 2447 —Bending fracture of the lower leg bones with a big lateral bending wedge Compare with roentgenogram in fig 2450

FIG 2448 —After reduction in the screw traction apparatus a stainless steel transfixion pin 15 cm long is driven through the upper and lower ends of the tibia

FIG 2449 —While traction is maintained an unpadded cast is applied from the knee to the tips of the toes Both pins fastened by rings and set screws Plaster covers over the ends so that the pins cannot rotate Later we used a pin through the calcaneus instead of the pin through the lower end of the tibia (Compare with figs 2453—2456) The cast should in all cases extend as high as the mid thigh in order to avoid inflammation of the proximal pin site

and shown in figure 2348 Special care must be taken to achieve a shortening of at least 3 to 5 mm and to avoid distraction After reduction another pin or wire is driven through the tibial tubercle A long leg cast is then applied as described on page 1675 If it is applied on the first or second day it must be split immediately throughout its full length If the cast is applied after the swelling has subsided it may remain closed Further treatment is carried out along the lines described on pages 1676 1677 When the cast is finished rings with set screws are mounted on the four ends of the pins The rings and set screws

my assistants to use this method because Kuntscher stated that the medullary nail promoted callus formation My re-examinations of our cases in 1943 and Krosl s[1] re examinations in 1953 unfortunately proved this statement to be false

Callus formation was often markedly delayed because the fragments had been driven apart at insertion of the medullary nail (M N /figs 430—441 816—893) In some cases the fracture cleft became visible again after some



2455 January 7 1931 2456 January 7 1931 2457 January 23 1937

FIG 2455 —*Open* torsion fracture of the tibia at the junction of the middle and distal thirds torsion fracture through the middle third of the fibula with posterior torsion wedge

FIG 2456 —Same after reduction in the screw traction apparatus with pins through calcaneus and upper end of tibia Good apposition of the fragments In 1933 we stopped using trans fixion *in torsion fractures It is better to apply a loose wire loop as shown in fig 2469*

FIG 2457 —Same case 6 years later After excision the wound healed without complication Bony union in ideal position good functional result

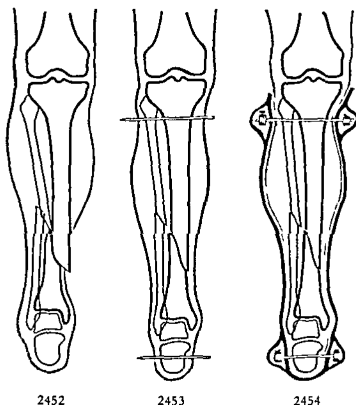
months (M N /figs 442—459) In a few cases the medullary nail was used where there was no or but little displacement (M N /figs 121—128, 138—142 430—441) Closed medullary nailing was sometimes accomplished within a few minutes, in some cases, however, it took a few hours During this time other patients remained untreated In 1944, when infection occurred in a case of

[1] Krosl Ergebnisse der Marknagelung bei Unterschenkelbruchen 54 Heft zur Unfall heilk 1956

Questions We Should Ask Ourselves in Order to Avoid Failures When Treating Closed Fractures of Shafts of the Tibia and Fibula in a Transfixion Cast

In addition to the questions given for treatment of closed fractures of the shafts of the tibia and fibula by continous traction and subsequent full leg walking cast (see pp 1800, 1808, 1822), the following should be answered

1 Have I purposely achieved a shortening of at least 3 to 5 mm and avoided all distraction before insertion of the nails?



Sketched in June 1931

Fig 2452 —Torsion fracture of tibia and fibula with valgus deformity

Fig 2453 Reduction by calcaneus pin traction in the screw traction apparatus Another 15 cm pin was driven through the upper end of the tibia

Fig 2454 —While traction is maintained a cast is applied from the knee to the tips of the toes The ends of the pins are mounted with set screws and covered with plaster The cast must extend to mid thigh

2 Have I mounted rings with set screws on the projecting four pin ends, have I covered the ends with bits of cellulose and included them in the plaster?

3 Have I split the cast immediately throughout its full length if it has been applied on the first or second day after injury?

4 Has the patient been kept from walking with his transfixion cast?

Treatment of Fresh Closed Fractures of the Shafts of Tibia and Fibula by Closed Medullary Nailing

From 1941 to the beginning of 1944 we treated 65 closed and 45 open fractures of the tibia and fibula with Kuntscher s medullary nails I permitted

16 Curved spring clip for the protection of the skin during introduction of the medullary wire (M N /figs 76, 934, 935)
17 A sterile metal ruler for measuring the length of the fragments and the medullary wires (M N /fig 80)
18 A sterile handle for inserting the medullary wires (Vol II/fig 1692)
19 Sterile pliers for introducing the medullary wires (Vol I/fig 145)
20 A hammer to drive in the medullary wires (Vol I/fig 127, M N /fig 74)
21 Sterile wire pincers
22 Skeleton of the lower extremity

Indication for Closed Medullary Wiring The indications and contra-indications for closed medullary wiring correspond to those of closed medullary nailing (see M N /p 248—250) This operation may be carried out in a patient in good general condition, on the day of the accident, only in a transverse fracture with displacement by a full shaft s width with or without shortening (figs 2458—2463) In flexion fractures with oblique fracture surfaces (figs 2413—2414) and in the presence of a flexion wedge (figs 2373 i, k) this operation is, as a rule, not necessary as good position can usually be maintained by traction Half torsion fractures (figs 2373 g, 2463—2466) may be treated by medullary wiring, if displacement by a shaft's width should occur in an exceptional case as shown in figure 2465

Poor general condition of the patient is a *contraindication* especially in the presence of other severe injuries Medullary wiring is no urgent operation It should, in general, be omitted in a patient with multiple fractures as the danger of fat embolism may be increased Neither must it be carried out during inflammatory diseases, especially in angina or furunculosis, or in the presence of infections in any part of the body

Warming the patient treating the shock, physical examination, local anesthesia of the fracture and pin sites reviewing the roentgenograms insertion of the calcaneus pin, application of the rotating stirrup and the protective cap, and positioning the patient on the screw traction apparatus, are carried out as described on pages 1705—1710, for treatment by traction

Positioning the Roentgen Tubes After the original roentgenograms, not sketches, have been displayed for ready reference during operation, a skeleton of the lower extremity is laid out The injured leg is placed on the screw traction apparatus One roentgen tube is positioned at the flexor side and another one at the medial side of the lower leg (M N /fig 804)

Reduction of the Fracture Traction of 5 to 6 Kg is exerted at the screw This usually suffices to correct shortening and lateral displacement In serrated fracture ends heavier traction is needed for correction of the lateral displacement If the fragments cannot thus be brought into apposition, the leg is taken out of traction and angulated as shown in Vol I/figs 16—18 Brief fluoroscopy confirms whether the fragments are well aligned If they do not remain in place but become re-displaced again and again, the fragments are fixed in the sagittal plane by two straps of bandage as shown in M N /fig 803 If necessary, straps of bandage may also be applied in the frontal plane The

closed medullary nailing and amputation became necessary — this being the *only amputation among our 1130 fresh closed fractures of the shafts of tibia* and fibula (for case history see M N/p 150) — I forbade medullary nailing of fractures of tibia and fibula in hospitals under my supervision The reports of A W Fischer, Ehalt and Stotz (see M N/p 144—163) on deaths and infection following closed medullary nailing supported my opinion I see no advantage in closed medullary nailing as against conservative methods (long leg cast initially or following continuous traction), on the contrary I see the many severe disadvantages

Closed Medullary Wiring of Fresh Closed Fractures of the Shafts of *Tibia and Fibula*

Since 1954 we have used closed medullary wiring in some unstable fractures of the shafts of tibia and fibula, especially in transverse fractures with displacement by the full width of the shaft with shortening, because redisplacement occurs often in these types of fracture Zrubecky [1] has reported on this subject

Medullary wiring consists in the introduction of one or more 2 mm stainless wires into the medullary space in unstable fractures (figs 2458—2466) *Lateral displacement of the fragments can be thereby avoided, recurrence of angulation is also diminished Contrary to medullary nailing, the fragments can readily approach each other after absorption of the devitalized fracture ends so that no separation between the fracture ends will ensue with all its detrimental consequences* (see Vol I/pages 25—27)

For medullary wiring of an unstable fracture of tibia and fibula the following are required

1 Local anesthesia (see Vol I/p 119 and fig 152)
2 True anteroposterior and lateral roentgenograms preferably 15×40 cm (figs 2458—2466)
3 A screw traction apparatus for the lower leg (Vol I/fig 101, M N/fig 308) or
4 a reduction apparatus for the lower leg (M N/figs 95 804) or
5 Wittmoser s reduction apparatus (M N/figs 99—103, 806) or
6 Kromer s reduction apparatus
7 *Two* portable roentgen tubes (M N/fig 804)
8 Two fluoroscopy screens (M N/figs 102, 103)
9 A fluoroscope (M N/figs 104—107)
10 Lead apron and lead gloves
11 Sterile cloth envelopes for the roentgen cassettes
12 Rapid developer (see Vol II/p 1315)
13 A transparent protractor (Vol I/fig 91) and ruler
14 Six to eight sterile 2 mm stainless wires 30 cm long
15 A straight and a curved awl for piercing the bone (M N/figs 72, 73, 797—800)

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[1] Zrubecky Monatsschr Unfallheilk *58* 86—92 1955



2464 January 31 1955 2465 February 7 1955 2466, July 2 1955

FIG 2464 — Half torsion fracture of the tibia high torsion fracture of the fibula Sustained by a 51 year old chauffeur who slipped on ice Lateral displacement of tibia by half of the width of the shaft

FIG 2465 — Same case after one week Calcaneus pin traction of 3 Kg Dorsal displacement by two thirds of the shaft s width As the fracture surfaces face away from each other reduction was performed in the screw traction apparatus and 3 medullary wires were inserted Traction of 1 Kg continued for 2 weeks Then long leg walking cast for another 9 weeks

FIG 2466 — Same case after 5 months Bony union in good position No significant decalcification



2467 February 10 1952 2468 February 19 1952 2469 May 12 1952

FIG 2467 — Half torsion fracture of tibia and torsion fracture of lower end of fibula Sustained by a 55 year old waiter who slipped on the road and fell Medial displacement by one third and dorsal displacement by two thirds of the shaft s width The distal fragment has been circumducted around the proximal fragment and is displaced medially so that the fracture surfaces face away from each other

FIG 2468 — Same case after 8 days Under continuous calcaneus pin traction of 3 Kg the distal fragment has been displaced dorsally by the full width of the shaft Loose wire loop applied Full leg walking cast 2 weeks later

FIG 2469 — Same case after 3 months Bony union in good position Moderate decalcification

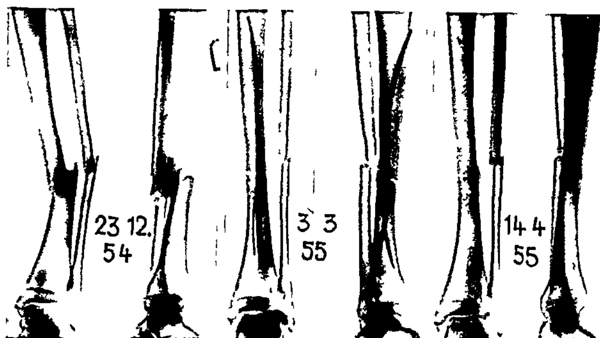


Fig 2458 — *Open* transverse bending fracture of tibia and fibula distal to the mid shafts *Wound excision under local anesthesia Reduced in the screw traction apparatus Insertion of* three medullary wires also under local anesthesia Lower leg splint calcaneus pin traction of 1 Kg Long leg walking cast after 25 days Patient could walk without the help of a cane 6 weeks after the accident and resumed his office work

Fig 2459 — Same case after 10 weeks at removal of the cast Bony union in good alignment shortening of 5 mm Lateral displacement of the fibular fragments allowed approximation of *tibial fragments*

Fig 2460 — Same case after 16 weeks The wires have just been removed under local anesthesia Solid bone structure Asymptomatic Full range of active motion of all joints

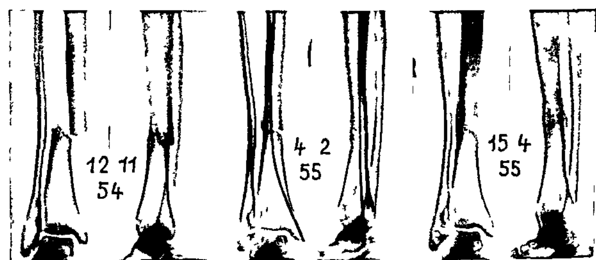


Fig 2461 — Closed transverse fracture at the junction of the middle and distal thirds of the tibia Reduction in the screw traction apparatus under local anesthesia Insertion of a medullary wire through the medial malleolus Calcaneus pin traction of 1 Kg on a lower leg splint Long leg walking cast after 3 weeks

Fig 2462 — Same case after 12 weeks on removal of the cast The fracture cleft is still visible at the medial side because the fibula was not broken and hindered approximation of the tibial fragments

Fig 2463 — Same case after 22 weeks Bony consolidation Normal calcium content Asymptomatic Free activ motion of all joints



2464 January 31 1955 2465 February 7 1955 2466 July 2 1955

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FIG 2469 —Same case after 3 months Bony union in good position Moderate decalcification

reduction apparatus shown in M N/fig 804, or Wittmoser's apparatus (M N/fig 806) is seldom needed

The fluoroscoping assistant must wear lead gloves and a lead apron to avoid *damage from* irradiation

Roentgenograms As soon as fluoroscopy confirms good position of the fragments, roentgenograms are made in both main planes to define accurately the amount of lateral displacement and angulation, and to measure the distance between the fracture site and the ankle joint

Local Anesthesia of the Site for Inserting the Wire This site should lie at least 10 cm proximal to the fracture and be on the medial side of the tibia There, the skin and the periosteum are rendered insensitive by 20 ml of a 2% Novocain solution

Sterile Draping of the Operational Field The surgeon begins to scrub up only after the fragments have been accurately reduced and strapped The upper third of the lower leg is then painted with iodine and covered with sterile drapes

Incision At least 10 cm proximal to the fracture site a 6 cm long longitudinal incision is performed down to the bone on the medial side

Curved Spring Clip (M N/figs 76, 934, 935) *This clip is laid on the skin* to protect it from pressure by the awl

Piercing the Tibia with the Awl The awl is drilled into the bone at a right angle When the cortex has been pierced, the awl is lowered so that it comes to lie almost parallel to the bone (M N/figs 797—800) In this position the hole is widened sufficiently

Introduction of the Medullary Wire When the right length has been measured in the roentgenogram the wire is inserted by a handle or pliers almost parallel to the tibia lest the wire be caught at the posterior cortex If necessary the wire may be driven forwards by slight strokes of the hammer The wire usually passes the fracture cleft without difficulty

Fluoroscopy in both planes confirms whether the wire lies well, or whether it has neither come out at the fracture cleft nor come too near the ankle joint The distance between the wire and the ankle joint should be 1 to 2 cm

Roentgenograms If it is felt that the wire lies well roentgenograms are made in both planes The central ray should be centered on the ankle joint

Cutting the Wire If the wire is inserted deep enough it is bent at a right angle and cut at 5 mm from the bone If the wire has been driven in too far it is withrawn a little

Introducing 2 or 3 Additional Medullary Wires If the medullary cavity is very wide two or three additional wires are introduced and cut off at the same distance from the bone as before

Skin Suture and Compression Bandage When the wires have been introduced, the wound is closed with 2 or 3 sutures A sterile compression bandage on the wound acts against the formation of a hematoma

Inserting a Medullary Wire through the Medial Malleolus If the fracture lies within 10 cm from the ankle joint the medullary wire is inserted from the medial malleolus (fig 2462)

Impacting the Fragments If there is a gap between the fragments they are impacted in order to avoid delayed callus formation by striking the heel with the flat of the hand or the fist

Placing the Leg on the Lower Leg Splint The leg is then placed on the lower leg splint and the calcaneus pin is weighted with 1 kg Since muscle pull, approximating the fragments, is stronger than this weight traction, there is no danger of distraction The pin ends are suspended in a way that the inner side of the foot is vertical (fig 2378 c) In this way the leg is better protected from circulatory disturbances than in a long leg cast which takes more time to apply and needs more material

Subsequent treatment is carried out as for fractures of the tibia and fibula treated by traction alone (see pp 1717—1724)

Application of the Full Leg Walking Cast When the swelling of the lower leg has subsided completely, i e, after about 10 to 12 days, a long leg walking cast, as described on pages 1724, 1725, may be applied A patient with so severe a transverse fracture should begin to walk not earlier than four weeks after the injury in order to avoid separation of the fragments due to the weight of the cast

Duration of Immobilization The cast can be removed 12 weeks after the injury Further treatment with an Unna's paste boot is carried out as in fractures without medullary nailing

Removal of Medullary Wires When removing the cast the medullary wires can also be removed under local anesthesia through a small incision in the old scar They can be palpated through the skin in some cases

Questions We Should Ask Ourselves in Order to Avoid Failures when Using *Closed Medullary Wiring in Fractures of the Shafts of the Tibia and Fibula*

1 Have I refrained from operating on a patient in shock?
2 Have I refrained from operating in the presence of associated severe fractures in order to avoid fat embolism?
3 Have I refrained from operating in the presence of any infectious foci (septic wounds boils angina)?
4 Have I operated only in fractures more than 8 to 10 cm from the joint ends?
5 Have I used two roentgen tubes at operation?
6 Have I accurately reduced the fracture before the operation?
7 Have I taken roentgenograms after reduction so that the position of fragments and the distance between the fracture cleft and the ankle joint can be well defined?
8 Have I worn lead gloves and a lead apron at fluoroscopy?
9 Has the site of insertion of the wire been chosen at least 10 cm proximal to the fracture cleft?
10 Has the proper position of the medullary wire been confirmed by fluoroscopy?
11 Have I after insertion of the medullary wires, obtained sufficiently large roentgenograms and centered the central ray on the ankle joint?

12 Have I impacted the fragments in the case of a gap between the fracture ends?
13 Have I placed the leg on a lower leg splint and weighted the traction with 1 Kg only?
14 Have I applied a long leg walking cast, but allowed the patient up not earlier than four weeks after the injury?
15 Have I removed the intramedullary wires after removal of the cast?

Open Medullary Nailing and Open Medullary Wiring in Closed Fracture of the Shafts of the Tibia and Fibula

Open medullary nailing or wiring, i e, with exposure of the fracture cleft, is not necessary in closed fractures of the shafts of the tibia and fibula, *since the fragments can always be reduced in the screw traction apparatus*

Loose Wire Loop in Closed Fracture of the Shafts of the Tibia and Fibula

Tight wire loops frequently lead to delayed callus formation and non union due to inability of the fragments to approach each other after devitalization and absorption of the fracture ends (figs 2470—2476) Therefore I introduced the *loose* wire loop in 1949 After reduction of the fragments in torsion fractures and oblique flexion fractures a wire loop is wound round the tibia Before knotting the loop, an angulated 4 mm Steinmann pin is placed temporarily between the bone and the wire loop When the pin is withdrawn after twisting the wire, the wire loop lies loose on the bone Thus, the fragments can overlap for 2 to 5 mm whilst lateral displacement of more than 2 to 3 mm is prevented Our cases treated with the loose wire loop have no longer shown delayed callus formation (figs 2467—2469)

Surgeons with little practice in this field should first train making wire loops or wire sutures on 4 to 5 cm thick wooden sticks sawed obliquely

Tight Cerclage with Wire Loops or Metal Bands for Treatment of Closed Fractures of the Shafts of the Tibia and Fibula

Firm fixation of the fragments by wire loops or metal bands (Putti, Parham) prevents approximation of the fracture ends after *devitalization* and absorption of the fracture surfaces Delayed callus formation and trans verse non union may ensue (figs 2470—2473) If, on the other hand, oblique bending fractures and torsion fractures are treated by traction with 1 to 3 Kg and, if distraction is carefully avoided non-union or infection (figs 2477—2482) will not follow

The dangers of tight wire loops namely delayed union and non union, and the long duration of treatment can be clearly seen from the following letter which the attending surgeon gave to the patient whose roentgenograms are shown in figures 2474—1476

Mr X a 34 year old merchant fell when skiing and sustained a spiral fracture of his left tibia and fibula on Jan 5 1955 We reduced the fracture on Jan 7 1955 and applied a wire loop after Danis Leemann As to the further treatment we should like to draw your atten tion to the following important points

1 *Immobilization in the cast* The duration of the immobilization depends on the severity of the fracture In this case *where four free fragments were encountered* we recommend applying a long leg cast for 12—14 weeks from operation

2 *Weight bearing* We urgently advise against weight bearing for the time the leg is still in plaster Early weight bearing even in so called walking casts leads to delayed fracture healing or non union as is known from experience

3 *Roentgen Control* Check roentgenograms are also of great importance for judging the progress of healing We particularly point out that *no periosteal callus* forms in fractures which are immobilized and not subjected to early weight bearing When such callus is visible this is a warning sign weight bearing should be stopped and immobilization in a long leg cast should be continued

Should pain swelling or reddening of the fracture site occur later on it is another warning against further weight bearing

4 *Incompatibility of Wire Material* As stainless steel has been used incompatibility of the wire material is rare Should such signs occur the wire loops may be removed 6—12 months after operation

This patient was severely handicapped in his commercial activities as he was not allowed to stand or walk on his injured leg At removal of the cast, 14 weeks after the accident, there was pronounced demineralization of the bones Severe swelling occurred and the patient could only walk with pain using two crutches When he began to walk with only one cane, six months after the accident, a painful reddening set in Eight weeks later the roentgenogram showed bending of the tibia and irritative callus (fig 2476) I have often seen fractures sustained while skiing which, when treated with firm wire loops, needed such a long time for healing or developed pain, swelling and reddening at the fracture site as mentioned in the letter In spite of ample doses of different antibiotics draining sinuses opened which only closed when the wires were removed Non union developed in other patients and finally law suits followed in some instances

For comparison I should like to mention the 32 year old surgeon (figs 2394—2401) who, in a walking cast, could walk without a cane and could perform his duty four weeks after the accident Four months after the accident he could again take up tennis, at a time when the above-described patient treated with firm wire loops still needed two canes for walking Also the hotel-proprietor whose roentgenograms are shown in figures 2402—2409 could walk without a cane and do his work 5 weeks after the accident, 15 weeks after the accident he rowed up the Danube 85 Km Six months after the accident he could perform all sports activities although some described the position of the fragments as unsatisfactory I know a patient with a similar position of fragments who was operated on, eight months after a skiing accident, to accurately align the fragments although the patient had been able to take five hours walks Although high doses of antibiotics were used, infection and a draining non-union ensued Several further operations were unsuccessful We have treated a number of patients who, after skiing accidents, had two torsion wedges and similar displacement as present in figures 2474—2476 They all were given long leg walking casts in the fourth week and their fractures were generally firm after 10 weeks The following winter they again could ski Having treated by conservative means more than 1000 torsion fractures of the tibia and fibula all of which united within a normal period of time and without occurrence of infection, I believe one can recommend this method Thus, the patient is protected from an unduly prolonged healing time and the surgeon avoids disagreeable lawsuits

12 Have I impacted the fragments in the case of a gap between the fracture ends?
13 Have I placed the leg on a lower leg splint and weighted the traction with 1 Kg only?
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2474 January 5 1955 — 2475 January 19 1955 — 2476 September 1 1955

FIG 2474 — Torsion fracture through the mid shaft of the left tibia with two torsion wedges and torsion fracture of the upper end of the fibula with a torsion wedge Sustained by a 35 year old merchant when skiing Treated elsewhere wire traction with 5 Kg for 2 days 4 tight wire loops full leg cast for 14 weeks

FIG 2475 — Same case 2 weeks later Good apposition of fragments Medial diastasis between the fracture ends

FIG 2476 — Same case 8 months later The fracture had appeared firm at removal of the cast Pain and reddening at fracture site for 10 days before taking this roentgenogram Fracture mobile Varus of 10° in spite of 4 wire loops Marked absorption of fracture surfaces mainly visible in lateral picture Periosteal callus at both sides of lowest wire loop No callus was visible 6 months after the accident Severe demineralization of ankle joint At removal of wire loops and onlay grafting a torsion wedge was found to be necrotic

Operative Treatment of Fresh Closed Fractures of the Shafts of Tibia and Fibula by a Loose Wire Suture

We have applied a loose wire suture in open short oblique fractures only, because a loose wire loop may slip off A hole is drilled in one fragment and the wire pulled through After reduction the wire is knotted loose over an angulated Steinmann pin as for a lose wire loop (see page 1758) Thus, the fragments can approach each other after superficial devitalization and adsorption of the fracture surfaces (figs 2487—2487 b)



Top 2470 November 4 1943 Bottom *2472 January 18 1944*

Top 2471 November 4 1943 Bottom *2473 May 6 1944*

Fig 2470—*Open* oblique fracture of lower third of right tibia and fibula with *open* avulsion fracture of medial malleolus Severe displacement Sustained by a 24 year old smith who was hit by a heavy piece of iron

Fig 2471 —Same case After accurate wound excision two tight wire loops were placed around the three fragments Four periosteal sutures secured the medial malleolus Long leg cast which was immediately split throughout its full length Windows were cut over the wounds the dressing of which was removed on the next day

Fig 2472—Same case after 11 weeks Lateral and posterior periosteal callus Fracture cleft broadened by absorption of the fracture surfaces

Fig 2473—Same case after 6 months Increase of callus which however has no contact at the fracture site The fracture cleft appears closed above but has become much wider below Appearance of beginning non union as in fig 2481 Marked absorption at upper wire loop Firm union of medial malleolus



Fig 2481—Draining non union of tibia one year after a closed torsion fracture which had been operated on with two firm wire loops similar to that in figs 2470—2473 Fracture area eburnated for a distance of 10 cm One large and a few small sequestra lie in the pseudarthrosis space Sustained by a 54 year old chauffeur who slipped in the street and fell

Fig 2482—Same case after 6 months The sequestra had been removed Walking cast for 4 months Bony union in good position Sinus closed

Operative Treatment of Fresh Closed Fractures of the Shafts of the Tibia and Fibula by Firm Longitudinal Wire Sutures

We have never applied a longitudinal wire suture in closed fractures of the shafts of the tibia and fibula Longitudinal sutures with 1 mm wire were, however used in seven open transverse fractures from 1947 to 1949 One or two wire sutures were used As they were so strong that they did not bend afterwards, they prevented the necessary approximation of the fragments Callus formation was severely delayed in all cases In one case, where a bending wedge was absent, non union resulted in spite of the wire giving way In our 267 re-examined cases of open fractures of the tibia and fibula the average time necessary for consolidation was 121 days whereas in the seven cases with firm longitudinal wire sutures it was 367 days, i e, three times as long We therefore soon gave up this method and use the medullary wire instead where the fragments can approach one another and callus formation is not delayed

Operative Treatment of Fresh Closed Fractures of the Shafts of the Tibia and Fibula by Screws

This operation is simple, but it also prevents the approximation of fragments which is necessary for a speedy consolidation of the fracture We used screws in only 3 cases of torsion fractures One case showed delayed



FIG 2477 —5 week old bending fracture of tibia and fibula which was operated upon at another hospital on the day following the accident Sustained by a 23 year old soldier who was kicked by a horse The medial flexion wedge was apparently removed at operation Diastasis between the fracture ends Draining sinus Screws are too short

FIG 2478 —Same case 2 months after removal of plate and screws The fragments have approximated as the fibula was not yet firm Fair callus Springy mobility of fracture



FIG 2479 —Same case after 7 months Fracture site thickened Fracture line still clearly visible Decreased calcium content Fracture firm

FIG 2480 —Same case after 10 months Bony structure bridges the fragments Calcium content normal A 3° varus and 8° recurvation because the cast was removed too early Asymptomatic

Method of Treatment

1	Plaster cast alone	306 (27 2%)
2	Pin traction alone	7 (0 6%)
3	Pin traction followed by full leg walking cast	664 (58 8%)
4	Transfixion	65 (5 75%)
5	Medullary nailing	65 (5 75%)
6	Other kinds of osteosynthesis	17 (1 5%)
7	Without treatment	6 (0 45%)

Of the seven patients treated by pin traction alone, six died within the first week due to severe concomitant injuries The seventh patient sustained also a femoral fracture In six (0 45%) patients the fracture remained untreated because five died within the first few hours due to severe concomitant injuries, and amputation was performed in one case of primary gangrene

The *average duration of treatment* amounted to 139 81 days, i e, 29 65 days in hospital and 154 85 days in the out-patients department

The average duration of treatment in the 65 cases of medullary nailing amounted to 167 9 days, i e, 42 2 days with the patient hospitalized and 125 7 days with the patient as out-patient In the 17 cases of other kinds of osteosynthesis the average duration of treatment was 187 4 days, i e, 32 5 days in hospital and 154 9 as out-patient

Deaths Of the 1123 patients 15 (1 3%) died while still in hospital, 3 (0 3%) from direct consequences of the fracture of tibia and fibula (one on the 13th day, another patient on the 43rd day from pulmonary embolism, a third patient on the 8th day from pneumonia) One patient died from grippe-encephalitis on the third day Eleven patients died from severe concomitant injuries, five on the first day, and six within the first week

Thus, in none of these cases was death a direct consequence of treatment, while Fischer and Maatz in 59 patients treated by medullary nailing lost one patient due to septicemia

Amputations Two patients (0 2%) among 1123 required amputation One due to infection following medullary nailing, the other after he had been admitted with beginning gangrene six days after the injury

Secondary infection of the fracture occurred in two patients (0 2%) Both were treated in plaster alone since there was no considerable displacement The cause of infection was primary damage to the skin with subsequent necrosis of the skin

Infection of the pin or clamp site occurred 15 times (2 5%) among the 605 patients treated with continuous traction and subsequent long leg walking cast Infection was so mild that neither incision nor sequestrectomy was necessary in a single case, and there was no draining sinus

Infection of the pin site developed in 10 (15 6%) of the *65 cases of transfixion* Thus it was six times as frequent among these cases as in cases treated with continuous traction Infection developed at the pin through the tibial tubercle in six cases, at the calcaneus pin four times Infection at the tibial tubercle occurred because at that time, we applied the cast only up

callus formation, consolidation took 10 months The two other cases healed within normal limits of time, viz, in 10 weeks

Operative Treatment of Fresh Closed Fractures of the Shafts of the Tibia and Fibula by Means of a Plate and Screws

Lane and Lambotte have introduced this technique If one or more plates are screwed into the fragments, the screws will prevent approximation of the fracture ends when they undergo superficial absorption and devitalization, no matter how accurately the fragments have been apposed at operation A gap will result between the fracture ends, as shown in figure 2477 Non-union and infection are very frequent with this technique as can be seen from the numerous reports mentioned in Vol I/pp 220—223 Lambotte had to remove 38% of all plates operated on from 1891 to 1919, and still 6% of all plates between 1920 and 1925 I have never used plate and screws for a fracture of the shaft of the tibia and fibula

Disadvantages of Operative and Advantages of Conservative Treatment in Fractures of the Shafts of the Tibia and Fibula

Wiggins, Bundens and Park, of Philadelphia, reported on the disadvantages of operative treatment in a total of 139 cases Hamilton and Jahna of the Accident Hospital in Vienna, reported on the advantages of conservative treatment *in the same numbers of closed and open fractures of the shafts* of tibia and fibula treated during the same period The results are as follows

	Total of cases	*Deformity*	*Non union*	Delayed *Callus* Formation	Osteo myelitis
Wiggins Bundens and Park[1]	139	11 (7 9%)	8 (5 75%)	7 (5 0%)	27 (12 2%)
Hamilton and Jahna[2]	139	0	0	5 (3 6%)	2 (1 4%)

End-results of 1130 Fresh Closed Fractures of the Shafts of Tibia and Fibula

Ender, Krotschek and Jahna[3] re examined our 1130 cases of fresh closed fractures of the shaft of tibia and fibula which had been sustained by 1125 patients in the 25 years from December 1925 to Dezember 1950 The punch card system (Hollerith) was used I[4] reported these results at the German Congress of Surgeons in 1953

1 Wiggins Bundens and Park Complications following open reduction and plating of fractures of tibia Am J Surg *86* *273—281 1953*

2 Hamilton R L and Jahna H Simple proven method or the treatment of fractures of the shaft of the tibia (with or without fracture of fibula) Am J Surg *88* 218—225 1954

3 Ender Krotschek and Jahna Behandlungsergebnisse bei 1130 geschlossenen Unterschenkelschaftbruchen 54 H ft z Unfallheilk 1956

4 Bohler, L Unterschenkelschaftbruche Langenbecks Arch u Dtsch Z Chir (Kongreßbericht) 276 193—216 1953

Active motion of the subtalar joint was limited by more than half in 60 (14%) of the 424 re examined patients The average age of these patients at the time of the follow up examination was 54 2 years The youngest patient was 16 years of age He had a transient distraction of 15 mm Only 20 of these 60 patients felt symptoms In the cases of medullary nailing the range of motion of the subtalar joint was limited by more than half in 33 3% of the cases

Active motion of the ankle joint was limited by more than half in 39 (9 2%) of the 424 re examined patients The average age of these patients at the time of the follow-up was 49 3 years The youngest was 16 In the cases of medullary nailing the ankle joint was limited by more than 10° in 12 1%

Active motion of the knee joint was limited in 22 (5 2%) of the 424 re-examined patients Loss of extension was in no case more than 5°, loss of flexion did not surpass 20° At the time of the re-examination 20 of these 22 patients were over 40 This shows that a patient below 40 will generally suffer no limitation of active motion of the knee in spite of immobilization necessary for treatment of a fracture of the shafts of the tibia and fibula The longest period of immobilization was 546 days The knee of this 39 year old patient showed free active motion at re-examination

Arthrosis Re examination revealed a surprisingly great number of arthroses of the talocrural and subtalar joints Among 424 re-examined patients, 87 (20 5%) showed arthrosis in the ankle region on X-ray, only 3 patients (0 7%) developed arthrosis of the knee joint Occurrence of arthrosis depended definitely on the patient s age at the time of accident, on the length of the follow-up period on concomitant injury of the ankle joint, and on the presence of angulation Every effort should, therefore, be made to avoid angulation It was striking that arthrosis amounted to only 10% of those patients who had been re-examined 2—5 years after the accident, but was detectable in 45 45% of the patients re-examined 23 to 26 years after the accident, 50% of the patients with arthrosis were asymptomatic

Muscle Atrophy Of 424 re-examined patients 8 (1 9%) had muscle atrophy of more than 2 cm (measuring the circumference of the leg)

Varicose Veins In 18 (4 2%) of the 424 re-examined patients pre-existent varicose veins became worse In 35 (8 25%) patients the varicose veins developed after the accident, in 18 patients only on the injured leg

Gait Among the 424 re-examined patients 390 (92%) had a normal gait Only 34 (8%) walked with a slight limp According to the patients' statements 63 (14 85%) said they were impeded in walking Most of these patients were covered by accident insurance at the time of the accident The average age of these 63 patients was 59 years at the time of re examination Four of these 63 patients declared they could walk for only one hour

Change of Profession Of the 424 re-examined patients 170 (30 8%) performed heavy labor Only 10 (2 4%) had to change their occupation because of the fracture of the lower leg bones The average age of these 10 patients was 51 5 years at the time of the accident

to the knee in transfixion Incision and sequestrectomy became necessary in two cases of infection at the tibial tubercle Thus, transfixion is more dangerous than continuous traction We have therefore discontinued transfixion

Infection followed medullary nailing in 5 of 65 cases (7 5%) One of these patients required amputation above the knee We have discontinued medullary nailing of fractures of the shafts of the tibia and fibula after this case

Non-union occurred in two cases (0 2%) Distraction was the cause in both cases though a traction weight of only 3 Kg had been used A careful study of the roentgenograms of these cases revealed that firm union would have almost certainly been achieved if immobilization had been continued long enough After these experiences one can say that every closed fracture of the shafts of tibia and fibula will, as a rule, heal by bony union if no diastasis between the fracture ends has been caused during treatment (figs 2422—2425) and if a primary diastasis has been abolished (figs 2418—2421)

Delayed callus formation occurred in 40 (3 8%) out of 1048 cases (the 15 deaths, the 2 amputations and the 65 cases of medullary nailing not included) We speak of delayed callus formation if bony union has not been achieved after 20 weeks (140 days) Of these 40 cases, 24 (60%) had a transient diastasis of 1 to 15 mm, or an average of 3 mm The period necessary for consolidation amounted to an average of 201 3 days as against 75 5 days in general

In the case of delayed callus formation it is rather difficult to decide whether an operation is indicated and when it should be performed Generally, an oblique osteotomy of the fibula suffices Operation on the tibia is seldom necessary *I have never performed partial excision of the fibula in closed* fractures of the shaft of the tibia since I have seen a number of cases of re-fracture of the tibia in patients operated on in other hospitals

Angulation Of 1048 cases (excepting all cases of death amputation, and cases with severe concomitant injuries)

997 cases (95 1%) showed no angulation,
48 cases (4 6%) had angulation of 6° to 10°
3 cases (0 3%) had angulation of 11° to 15°,
no case had angulation of more than 15°

Shortening as measured in the roentgenogram The following shortenings were found in the 1048 patients after completion of treatment

742 cases	(70 8 %)	shortening of 0— 5 mm,
295 cases	(28 15%)	shortening of 6—10 mm,
6 cases	(0 6 %)	shortening of 11—15 mm
5 cases	(0 5 %)	shortening of 16—20 mm

There was never a shortening of more than 2 cm

From now on the end-results of only 424 patients are quoted namely the number of patients who have come for re-examination

Active motion of the toes was limited in 18 cases (4 2%) In patients treated by medullary nailing the toes were limited in 18 2%

Table 2 *Comparison of the Number of Patients Drawing Permanent Pensions after Closed Fractures of the Shafts of the Tibia and Fibula Covered by Accident Insurance*

Year	Author	Total of Cases	Number of Patients Drawing Permanent Pension
1904	Thiem	1554	699 (45.0%)
1922	Troell	372	73 (19.6%)
1926	Schaffler	144	24 (14.6%)
1927	Cornioley	345	141 (40.9%)
1929	Rutz	63	59 (93.7%)
1936	Lundgren	302	62 (20.5%)
1952	Meier Stauffer	100	10 (10 %)
1953	Ender Bohler	554	55 (9.9%)
1953	Reisinger	1255	485 (38.6%)

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96 FRESH OPEN FRACTURES OF THE SHAFTS OF THE TIBIA AND FIBULA

Of all open fractures of the shafts of long bones, those of the tibia and fibula are the most common, as the anterior edge and the medial surface of the tibia lie immediately under the skin Of our 306 open fractures of the long cylindrical bones, treated from 1926 to 1934 (Ehalt [1]), 186 (68%) were fractures of the tibia and/or fibula, namely, 127 (41%) fractures of the tibia and fibula, 30 (16%) of the tibia, 6 of the fibula, and 23 of the malleoli Meanwhile the number has increased sixfold

Origin of the Open Fractures of the Shafts of Tibia and Fibula They result much more often from direct than indirect force, i e, *in the same way* as closed fractures of tibia and fibula (see p 1694), but are, as a rule, caused by greater violence

[1] Ehalt W Behandlung der Bruche der langen Rohrenknochen Vienna Maudrich 1938 Tratamiento de las fracturas abiertas Barcelona Editorial Labor 1940

Average Duration of Sick Leave Patients covered by industrial accident insurance returned to work on an average of 156 days Patients who were not insured resumed work after 123 days

Compensation Among the 1123 patients with 1130 fractures of the lower leg, 554 were industrial accidents covered by insurance, 55 (9 9%) of them draw a permanent pension Of these, 34 (61 8%) were over 50 years at the time of the accident Most of them had suffered from circulatory disturbances or already showed roentgen evidence of arthrosis of the injured leg before the accident In three of the patients drawing permanent disability compensation the fractured leg already had been damaged before the accident, namely, by poliomyelitis, osteomyelitis and by syringomyelia These 37 cases of the 55 drawing permanent disability compensation show our liberal attitude towards disability pensions as against other countries where disturbances which had existed before the accident are not considered for compensation In 13 patients the cause of the permanent disability pension was circulatory disturbance of the leg due to either post-traumatic thrombosis or increased varicose veins, or the pension was for traumatic arthrosis

Table 1 *Comparison of the Average Duration of 100/ Disability in Patients Insured Against Industrial Accidents Who Suffered Closed Fractures of the Shafts of the Tibia and Fibula*

Year	Author	Cases	Total Disability In Days
1922	Troell	372	156
1923	Cornioley	432	135 5
1925	Jager	187	111 7
1927	Cornioley	345	152
1933	Magnus	451	120 3
1934	Zollinger [1]	490	171 6
1936	Lundgren	302	170 4
1952	Meier Stauffer	100	158
1953	Ender Bohler	554	156

In only five cases was the permanent disability pension a direct consequence of the treatment, namely, two cases of non union due to distraction, two cases with limitation of ankle joint motion, muscular atrophy, and impeded walking capacity following delayed callus formation due to distraction, and one amputation following medullary nailing

This again proves that distraction (separation of the fracture ends by excessive traction) and medullary nailing cause severest disturbances

Reisinger surveyed the case histories and files of the 1291 closed fractures of the shafts of tibia and fibula of the Compensation Insurance Institute for Employees in Agriculture and Forestry of the Western Provinces of Austria which had been incurred from 1939 to 1948 Of these patients 36 were treated in the Vienna Accident Hospital and 1255 in other hospitals Of the 36 patients treated in the Accident Hospital 4 (11%) draw a permanent disability pension, of the balance (1255 patients) 485 (38 6%)

[1] Open and closed fractures

caution so as to avoid unnecessary pain Examination of these two joints, however, must not be omitted lest femoral fractures and especially dislocations of the hip and knee be overlooked

Treatment of Fresh Open Fractures of the Shafts of the Tibia and Fibula

The general rules for reduction, immobilization and exercises apply as in closed fractures of the tibia and fibula (see pp 1700—1703)

The material necessary for traction and the *bed* are ordered as for closed fractures (see p 1704)

Treatment of Shock If the patient is in shock he is treated as described in Vol I/p 134 and Vol II/p 1089

For *reduction* and *immobilization* the same equipment is needed as for closed fractures of the shafts of the tibia and fibula (see pp 1666 and 1705) Instead of the lower leg splint an oblique splint with a pulley is used (fig 2485 a) For excision of the wound scalpels, scissors, forceps, wound retractors, chisels, hammer, and a rongeur (Luer) are required

Local anesthesia of the fracture sites and the pin sites, the roentgenograms, checking the equipment listed on pages 1666 and 1705, study of the roentgenograms, insertion of the pin or wire, and application of the rotating stirrup and the protective pin cap, are carried out in the same manner as in closed fractures of the shafts of the tibia and fibula (see pp 1706, 1707)

Avoidance of Wound Infection The most important and most effective means for avoiding infection is thorough excision of the wound within the first hours after the injury Secondary infection from sloughing of the skin can be avoided by closing the skin without tension Skin graft may be necessary in some cases Antibiotics can act well only after wound excision and in the presence of normal skin

Time and technique of wound excision, preparation of the patient, local anesthesia and its effect on shock roentgenograms and cleansing the skin are described in Vol I/pp 146—149

Wound Excision If the patients are received for treatment within the first 8 to 10 hours after the injury, the wounds are accurately excised under local anesthesia according to the rules given in Vol I/pp 149—174 Under protection of antibiotics the time may be extended up to 24 hours in some cases The wound must usually be enlarged proximally and distally by suitable longitudinal incisions in order to uncover all cavities and pockets of the wounds and their torn and soiled tissues All torn and crushed parts of the proximal and particularly the distal muscle stumps must be carefully removed down to well nourished tissue The skin must always be incised in a longitudinal and never in a transverse direction All devitalized tissue must be removed but not 1 mm more than necessary Blood vessels and thin nerves must carefully be preserved Also the bones must accurately be cleaned with chisel and rongeur Bone splinters still in connection with periosteum must not be removed Bleeding vessels are clamped but not ligated for reasons given in Vol I/p 151 Suture fistulas can thus be avoided (Koch's[1] report) When the

[1] Koch F W Der Chirurg 23 520—522 1952

Types of Fracture Bending fractures are much more common than torsion fractures The ratio in our 461 open cases is 90% to 10%, while in our 1130 closed cases 43% are bending and 57% are torsion fractures

Site of Fracture and Wound Most bending fractures are in the mid-shafts (figs 2487, 2492—2508) In 90% of all cases the wound is anterior or medial (fig 2486) Torsion fractures occur usually *at the junction of the middle* and lower thirds Here, the pointed tip of the proximal fragment pierces the skin In fractures caused by direct force skin and soft tissues are, as a rule, much more damaged than in those caused by indirect force According to Zrubecky[1] 50% of our 461 open fractures caused by direct force and with direct wounds were combined with a fracture caused by indirect force, and with another wound Torsion fractures with a *fracture end piercing the skin* are less dangerous than flexion fractures as the wound is usually smaller and the bone often not soiled at all, while in fractures caused by direct force foreign bodies full of pathogenic organisms enter the wound

Complications Following Open Fractures of the Shafts of the Tibia and Fibula

Early Complications	Late Complications
1 Death	1 Angulation, shortening, and rotation
2 Amputation	2 Delayed callus formation and non-union
3 Progressive spreading infection	3 Draining sinus and sequestrum
4 Skin necrosis	4 Ulcers
5 Circulatory disturbances	5 Dystrophic disturbances (muscular atrophy, demineralization, cyanosis, edema, claw toes, pes cavus)
6 Nerve damage	6 Arthrosis
	7 Pain and limitation of motion

Origin and avoidance of early and late complications following open fractures of the tibia and fibula are described on pages 1784—1788

Diagnosis of a fresh open fracture of the tibia and fibula is simple if, besides the wound deformity and abnormal mobility can be seen At examination, the degree of shock must be confirmed (paleness of face, profuse perspiration, pulse blood pressure) Variations of shape, color (pale, cyanotic), and skin temperature must be observed The type of the wound is described and its size is measured in centimeters estimates and comparisons (coins etc) should be avoided The dorsalis pedis and posterior tibial pulses must also be palpated If the pulse cannot be felt on the injured side, but is palpable on the sound side, the vessels are either wedged between the fracture ends or torn In these cases the pulses must again be checked immediately after reduction The future of the limb depends primarily on the circulation Then the reflexes are examined as well as the mobility of toes, the ankle and subtalar joints Motion of the hip and knee joints should be checked with

[1] Zrubecky Behandlung und Behandlungsergebnisse von 461 frischen offenen Unterschenkelschaftbruchen Hefte zur Unfallheilk 1956

1747—1749 and figs 2447—2457) We discontinued use of transfixion in 1933

Closure of the Wound Without Tension When all foreign bodies with their adherent germs and all torn, bruised, and devitalized tissues have been removed, one to three drains are inserted and the skin is closed by closely placed sutures, if this causes no tension No ligatures or deep sutures are buried If the skin, and only the skin, is closed by closely placed sutures no new germs can enter the wound from outside A wound of more than 12 hours standing may only be sutured if it is not covered by a purulent or smeary layer

Danger of Wound Excision and Wound Suture Excision of the wound may become dangerous if it is not carried out with proper technique Neither too much nor too little may be excised *It is especially dangerous if in fresh wounds, as happens so often, only the edges of the wound are freshened and sutured, or closed by clips, without completely removing all devitalized tissue and all foreign bodies which have entered the wound* Pathogenic germs and foreign bodies which remain in the closed wound may cause severe spreading cellulitis, gas gangrene, and tetanus Purulent wounds or wounds of more than 24 hours standing must not be closed even by loose sutures Fatal complications may arise in spite of the use of antibiotics

Repair of Skin Defects Secondary infection may ensue in spite of accurate wound excision performed in time, if the wound cannot be closed without tension *The fate of every open fracture, after thorough debridement with the scalpel, depends on the condition of the skin* In case of a primary loss of skin, or, if parts of the skin have been so severely damaged by the trauma that they must be excised at the debridement, or, if soft tissues are swollen, the defect of skin must be closed by making one or two suitable longitudinal incisions and sliding the flaps thus gained The incisions for relaxing tension must lie at least 5 to 7 cm distant from the edges of the wound In narrower flaps danger of sloughing may arise The flaps should not be disconnected from the underlying tissue lest the circulation be endangered If a skin flap becomes necrotic, the resulting skin defect will be larger in size than originally Avulsed flaps of skin must not be used as sliding grafts — as their circulation is, as a rule, severely impaired Relaxing incisions must neither be placed over bones lying subcutaneously nor over a joint The defect caused by the relaxing incision is covered by split thickness (dermatome skin grafts (fig 2486) or Reverdin s pinch grafts (see Vol I/pp 158, 159 and figs 157—158 c, figs 2489, 2490) either immediately or 5 or 6 days later Exposed bone must not be covered by dermatome, Thiersch, or Reverdin grafts, because the transplanted skin will not take on bare bone

Wound Dressing by Thin Sterile Sponges of Adequate Size After suture of the skin the edges of the wound are painted with Mastisol (adhesive solution) The wounds are covered with an 8 layer gauze sponge which reaches beyond the wound edges by only 1 to 1 5 cm The rubber drains are protected by gauze sponges 2×2 cm If thick and large sponges are used, which pad the cast, the fragments may become displaced, may press on the damaged skin and may cause sloughing of the skin

wound has been accurately cleaned, 1 to 3 drains are inserted to avoid tension from hematomas The drains pierce the skin at the lowest points of the wound cavity but must never be led through the interosseous space They are sutured to the skin I have reported on the results of débridement[1] in 1955

Amputation If the foot is pale and cold, and if débridement reveals that vessels and nerves have been torn, amputation must not be delayed If, with preserved vessels and nerves, the skin tube is missing for more than half the length of the lower leg, if a large part of the muscles has been torn, and repair of the skin defect is not possible amputation should usually be performed If the pulse cannot be palpated after wound excision and reduction, circulation of the foot must be checked every hour If the toes have remained anesthetic, pale and cold after a few hours, and if the blood does not return upon pressure on the toenails, even though the cast was split throughout its full length and opened wide, amputation must not be delayed for more than 6 to 8 hours since severe complications may follow, such as gas gangrene, malignant edema, and progressive spreading infection, which would all seriously endanger the patient s life Some patients object to amputation as they still can move their toes This, however, is no sign of the foot s viability as the motion of the toes may be caused by muscles lying proximal to the torn vessels

Use of Antibiotics Penicillin and Streptomycin are given regularly before and after excision of the wound until the patient has been without fever for 3 days Antibiotics are a great help against infection Severe infections have become rare since their administration Of greatest importance, however, are accurate wound excision insertion of drains avoidance of necrosis of the skin by closing the skin without tension, and, if necessary skin graft

Reduction of the Fragments If amputation is not necessary, the fragments are reduced by pin traction in the long axis of the bones In transverse or short oblique fractures reduction is performed by means of single-pronged bone hooks or if necessary, by angulation to a right angle (see Vol I/figs 16—18)

Osteosynthesis in Unstable Fractures of the Shafts of the Tibia and Fibula In unstable fractures, subsequent lateral displacement of a fragment may cause pressure necrosis of the often severely damaged skin, secondary infection may follow Osteosynthesis is therefore indicated in some cases to avoid such displacement

Open medullary nailing cerclage by firm wire loops or metal bands firm transverse or longitudinal wire sutures and the use of plates and screws have proved failures due to danger of infection and non-union (see pp 1751, 1758—1764) At present we use *medullary wires* (see pp 1752—1757 and figs 2458—2466) in severely displaced transverse fractures and in unstable oblique fractures In some cases of long oblique fractures, or in torsion fractures with severe displacement, we apply a *loose wire loop* (see p 1758 and figs 2467—2469) or a loose wire suture (see p 1761 and fig 2447) In comminuted fractures (fig 2492) some surgeons use the transfixion method (see pp

1 Bohler L Munchen med Wchnschr 97 1247—1251 1955

of the leg, from the tips of the toes up to the flannel strip Two plaster bandages are spirally applied Then, a 75 cm plaster splint is made and divided into three equal parts, which are then applied at the medial, lateral, and anterior aspects of the knee For fixing the pin properly, a 4×4 cm eight-fold piece of plaster bandage, cut up to its center, is applied on both sides and two or three plaster bandages are wrapped around They must be carefully molded around both pin ends

Objections to the Short Lower Leg Cast Until 1940 we used to apply a cast extending up to only the knee (fig 2485) As that cast did not immobilize the fragments sufficiently, but allowed redisplacement of the fragments with subsequent sloughing of the skin and infection, we now apply the long leg cast (fig 2485 a) in all cases

Fluoroscopy of the lower leg is quickly performed in both projections Angulation can still be corrected in the soft cast

Third Roentgen Check As soon as the cast has hardened, new roentgenograms are made exactly from the front and exactly from the side to confirm the success of reduction

Placing the Leg on an Oblique Splint and Applying Continuous Traction If the roentgenograms show good position of the fragments, the calico suspension bandage is cut off and the leg is placed on an oblique splint with a pulley attached (fig 2485 a) Continuous traction of 5 to 6 Kg is applied at the calcaneus pin

The *splitting of the cast* throughout its full length over the inserted cord must be carried out before the patient leaves the plaster room, in order to avoid circulatory disturbances

Fenestration of the Cast Windows are cut over the sutured wound and over the drain sites The windows should not be wider than 3 cm If relaxation incisions have been made, windows must also be cut over them The windows should not reach beyond the edges of the wounds by more than 1 cm Some readers may consider these accurate measurements pedantic We have, however often seen that large, thick sponges on the wounds and large windows cause renewed displacement of the proximal fragments in spite of good primary position Sloughing of the damaged skin, with infection of the fracture site and all other complications may follow if too large a window allows the proximal fragments to move Zrubecky confirmed this when he reviewed our 461 open fractures of the tibia and fibula When the windows have been cut, the cut out piece of plaster is put back into the window as a cover in order to avoid a hematoma Splitting the cast and fenestration must be carried out immediately when the patient is still in the plaster room and under the effect of the local anesthesia Later on this would cause much pain the wounds would be more irritated and might even become infected Moreover another doctor, who continues with the treatment, would not know where the wounds are

Trimming the cast at the toes, cleaning the toes, clearing the cast of particles with the vacuum-cleaner inscription, and checking of the roentgeno-

Immobilization of the Leg in a Split and Windowed Long Leg Cast The equipment listed on pages 1666, 1667 is required

Positioning the Leg on the Long Screw Traction Apparatus After the wound excision a sling is applied to the uninjured foot The patient is then placed on the screw traction apparatus The sound leg is fastened to the foot plate Spring scales are inserted between the rotating stirrup of the injured leg and the hook of the traction screw The 0 5×12×18 cm pad is placed under the knee The 10 cm wide calico bandage with the incorporated wooden spatulae is placed over this pad The knee is suspended in extended position The two limbs of the calico bandage are kept apart by the 2×10×25 cm wooden spreader lest they press on the bone (fig 2348)

Fractures, which have been reduced and stabilized by means of a medullary wire, or a loose wire loop, or a loose wire suture, may be casted off hand like closed fractures of the tibia and fibula (see p 1725)

Reduction Screw traction is steadily increased up to 5—8 kg Thus, good position can usually be achieved The blood vessels are restored to normal and become again patent if they were wedged between the fragments

First Roentgen Check (Size of Film 15 × 40 cm) To confirm the result of reduction roentgenograms are made exactly from in front and exactly from the side Above all, one must confirm that no separation in the long axis (diastasis) has been caused by the longitudinal traction Then, one should see to it that the lateral displacement does not amount to more than a quarter of the shaft s width and that there is no angulation

Correction of Diastasis, Lateral Displacement, Valgus and Antecurvature In the case of diastasis the longitudinal traction is released and the bone impacted, if necessary In lateral displacement traction in the long axis is increased to gain space for apposition of the fracture ends In damage to the skin, usually situated anteriorly, it may be expedient to create a varus and recurvation of 5° to 10° each to relax the skin To correct a valgus deformity the rod holding the calico bandage is moved slightly lateral To correct an antecurvature the knee suspension sling or the traction cord is slightly elevated To confirm the good position fluoroscopy is done in both projections If this shows satisfactory position of the fragments the *second roentgen check* follows in accurate anteroposterior and accurate lateral projections

Renewed Reduction If there is still lateral displacement by more than the quarter of the shaft s width one must once more strive to correct it by increasing longitudinal traction New attempts at reduction must not be repeated more than twice particularly in damaged skin, because of danger of infection

Application of the Full Leg Cast If the roentgenograms show good position of the fragments in both projections the upper end of the thigh is dabbed with 5 or 6 longitudinal strokes of mastisol (skin adherent) Over them the 5×70 cm flannel strip is placed in such a way that both ends cross laterally and not in front It must not form wrinkles Then the 100 cm long hemp cord is placed on the leg as described on page 1656 A splint, 100 to 110 cm long is made of two plaster bandages and applied at the posterior aspect

of the leg, from the tips of the toes up to the flannel strip Two plaster bandages are spirally applied Then, a 75 cm plaster splint is made and divided into three equal parts, which are then applied at the medial, lateral, and anterior aspects of the knee For fixing the pin properly, a 4×4 cm eight-fold piece of plaster bandage, cut up to its center, is applied on both sides and two or three plaster bandages are wrapped around They must be carefully molded around both pin ends

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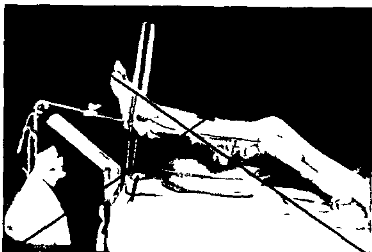
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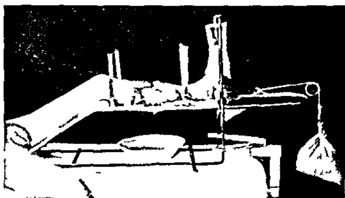
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Trimming the cast at the toes cleaning the toes, clearing the cast of particles with the vacuum-cleaner inscription, and checking of the roentgeno-



2483 October 16 1916

Open infected gunshot fracture of the lower leg poorly arranged on the splint The wrapping of the splint has slipped from the central end As too much of the bandage has been left away for treatment without dressing the calf bulges down and is swollen with edema There is *foot drop* because the foot has not been suspended The lower end of the splint has slipped down to the lower end of the bed because the splint has not been fixed by the scissor shaped *spreader The pulley for longitudinal traction is mounted on a wooden support A sandbag is* used for traction its weight cannot be confirmed The lower end of the bed has not been raised



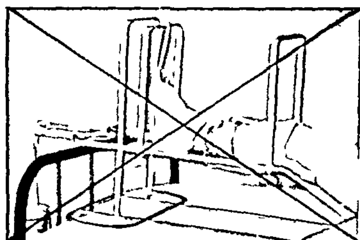
2484 January 6 1917

Well arranged *open* gunshot fracture of the lower leg There is a small window below the calf Therefore no window edema has resulted The foot is suspended and the lower end of the splint attached by means of the scissors shaped spreader The pulley is connected with the splint The sandbag used for longitudinal traction is smaller than that of fig *2483 Dish* below the calf to receive pus in exposed wound treatment

grams, the cast, the roentgen sketch and the inscription are carried out as in closed fractures of the lower leg (see pp 1725—1729)

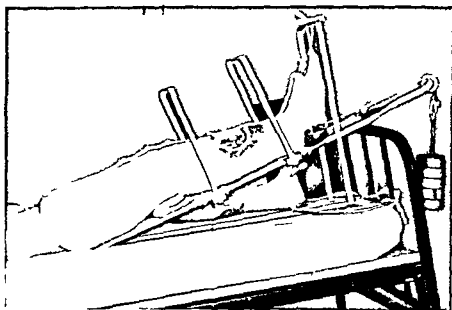
Suspension of Fore Foot to Avoid Rotary Displacement A hole is drilled through the toe plate A bandage is then pulled through it and the foot is suspended on the transverse bar of the oblique splint in order to avoid rotation

Applying Two U-supports to Protect the Wound from the Blanket To keep the blanket off the wound and in order to keep the blanket clean in the



2485 May 24, 1930

Open fracture of the lower leg bones, after exact excision of the wound insertion of drain suture of the skin reduction in the lower leg screw traction apparatus in a split cast which extends only as far as the knee In such a short cast angulation occurs frequently Therefore we now apply a cast extending up to the hip as shown in fig 2485 a



2485 a July 20 1955

Open fracture of the lower leg bones after exact excision of the wound insertion of drain suture of the skin reduction in the screw traction apparatus and application of a cast extending up to the hip The cast was split immediately and windowed The leg is placed on an oblique splint Continuous traction of 5 Kg The fore foot is suspended to avoid rotary displacement Two stirrups are attached to support the blanket The lower end of the bed is raised 30 cm The wooden box has been provided for the sound foot

case of a purulent wound, two U-supports are applied (fig 2485 a) and a gauze veil is spread over them

Positioning the Patient in the Bed As soon as the cast has been split throughout its full length fenestrated, cleaned, and inscribed, the patient is placed with the oblique splint and the traction weights into the pre-warmed bed The splint is then fastened to the lower end of the bed A wooden box is supplied for the uninjured foot A radiant heat cradle serves to dry the cast



FIG 2486—*Open* fracture of the tibia and fibula sustained by a 21 year old laborer who was hit by a concrete pillar At the anteromedial aspect a 22 cm long contused and lacerated wound with torn and badly soiled muscles The upper tibial fragment protrudes 10 cm from the wound 2 cm long wound at the calf Treatment consisted of exact wound excision under local anesthesia and loose wire suture In order to close the wound without tension a 15 cm relaxation incision was made at the lateral aspect of the lower leg Closure of the skin without burying deep sutures or ligatures Long leg cast which was split immediately throughout its whole length and windowed over the wound and the relaxing incision 5 days later the skin defect at the site of the relaxing incision was covered by a 3×15 cm dermatome graft The wound healed with 3×1 cm dry necrosis of the skin The photograph in the center and at the bottom show the healed lower leg Shortening of 8 mm Free range of active motion of all joints Three and one half years after the accident a 2×3 cm ulcer developed can now carry out unskilled work regularly

Determination of the Traction Weight If a loose wire loop or a loose wire suture has been applied, no longitudinal traction is necessary Nor is traction necessary when medullary wires have been used in transverse or short oblique fractures for stabilization In fractures without osteosynthesis traction of 5 to 6 Kg is applied, depending on the patient's muscular strength and age Double the amount of traction is used, as for continuous



FIG 2487 —Roentgenograms of fig 2486 Oblique bending fracture of right tibia and fibula with shortening of 4 cm The laceration of the soft tissues can be well seen in the lateral view

FIG 2487 a —Same case 5 months later Wire is guided through a drill hole of the proximal fragment and laid loosely around the distal fragment The fracture cleft is well discernible medially and anteriorly Good callus formation laterally and dorsally as in Vol I/figs 296 to 299 Fracture clinically firm

FIG 2487 b —Same case after 11 months Sound union of fracture



FIG 2487 c—Photograph re fig 2486 after 4 years With exception of limitation of dorsiflexion at the talocrural joint all joints can be actively moved through their full range

traction without a cast, because the cast causes heavy friction on the underlying surface Otherwise, the same rule applies for the traction weight as has been laid down on pages 1713, 1714

Further Treatment of Open Fractures of the Tibia and Fibula by Split Long Leg Cast and Simultaneous Traction

Observation of the Circulation The circulation of the toes must be particularly observed If the toes become swollen or if pain sets in, the cast must be opened up as early as the first night

The daily check of the patient's general condition and of the traction weight the marking of the fracture site for easier centering the roentgen tube, care for regular evacuation of the bowels, notes on the patient's overhead board and temperature charts and the *Grand Rounds* are carried out as in fractures of the femur (see Vol II/pp 1200—1202)



2488 November 20 1934 2488 a May 4 1954

FIG 2488 *Open* transverse fracture of tibia and fibula with large wounds and extensive avulsion of the skin Sustained by a 44 year old salesman who was wedged between a street car and a truck

FIG 2488 a —Same case 20 years later Bony union with valgus of 5° No arthrosis



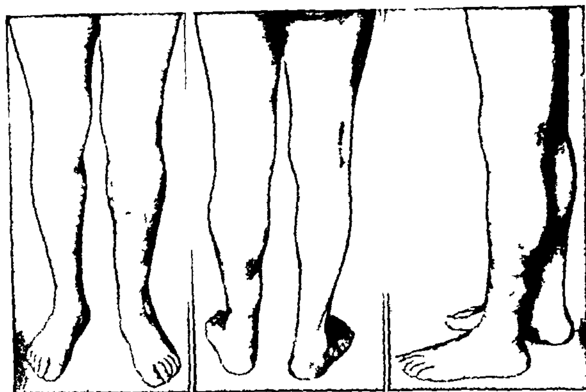
2489 February 11 1935

FIG 2489 —Photographs same case Loss of skin around the whole circumference ten weeks after the accident

Fourth Roentgen Check On the second day roentgenograms are again made in both projections mainly to exclude the existence of a gap (diastasis) between the fracture ends Should this be the case, the traction weight should be decreased In marked shortening traction will be increased Angulation or lateral displacement cannot and must not be corrected while the leg is in the cast

Wound Treatment Without Dressing On the day following the accident the gauze sponges are removed from the wounds and they are treated without any dressing Since the surrounding skin is frequently abraded to a great extent, it starts oozing if it remains covered The bandages become damp the skin macerated, the suture infected, and through its openings infection may penetrate into the deeper layers to the fracture, opened tendon sheaths, and fascial and joint spaces On the other hand, by treatment with no dressing the blood and serum dry, forming a crust which seals the wound tightly Healing takes place under the dry crust

Removal of Rubber Drain When the sutured wounds are exposed for treatment without dressing, the rubber drains are removed, too The sites of



December 3 1936

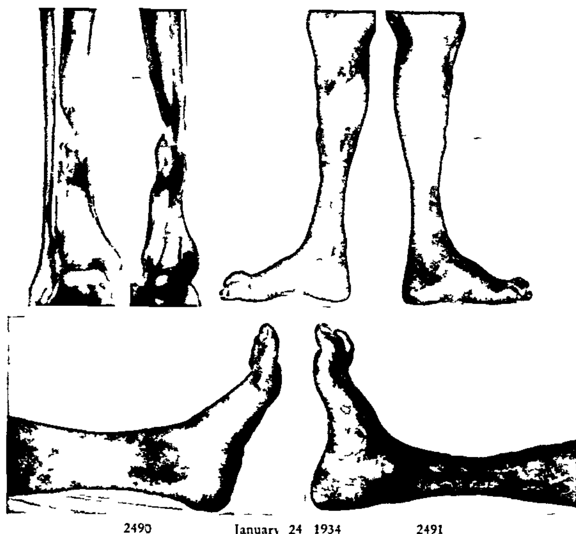
FIG 2489 a—Photographs to figs 2488 2489 two years later The extensive wound was covered with Reverdin s pinch grafts The donor area at the anterior and posterior aspects of the thigh can hardly be seen Throughout the follow up period of 20 years an ulcer has never developed The valgus of 5° is discernible Ankle joint limited by 10° Can walk well

drainage, however, must not remain without dressing but must be covered by gauze with Peruvian balsam If the drain sites are left uncovered infection may spread from them

What to Do When Fever Arises The patients temperature may rise to 40 C in the first few days If the wound, which is without a dressing and therefore open to inspection, remains dry and if there is no swelling of the inguinal glands, one can await developments The elevated temperature usually subsides in 8 to 10 days If swelling and reddening set in, some sutures must be removed for releasing the tension

Fifth Roentgen Check One week later new roentgenograms are made in both main projections to exclude diastasis

Warning against Attempts at Correction of Position within the First Few Weeks In the case of diastasis between the bone ends (separation in the long axis of the bone) the traction weight must be decreased Any attempt at correction of a lateral displacement must, however, not be undertaken Severe infection in spite of previously normal wound healing may flare up if the cast is removed for correcting lateral displacement or angulation whether such correction be carried out by manual force or by means of the screw traction apparatus Many a case with severe infection following such manipulation has been admitted to our hospital (see Vol I/p 162, and figs 2505—2508) Angulation, particularly recurvation (posterior bowing), can easily be corrected if,



2490 January 24 1934 2491

Fig 2490—Top left Defect pseudarthrosis of right tibia after open fracture of the tibia treated in another hospital by continuous traction of 7 Kg for 6 months Severe demineralization Bottom left Photograph of the uninjured left foot for comparison

Fig 2491—Top right and bottom right Photographs to fig 2490 Pes calcaneo cavus with claw toes *Severe muscle atrophy We have never seen such a picture among our cases as we have never used such heavy traction*

4 weeks later, when the cast is removed traction weight is decreased to 2 to 3 Kg and the foot sling is suspended at suitable level

Closure of the Cast When the swelling of the lower leg has subsided after 5 to 10 days the cast becomes too wide It must be closed by winding a bandage round it to avoid angulation, especially in valgus

Skin Necrosis If necrosis of the skin occurs it must not be excised lest the bone exposed Dry necrotic skin will fall off by itself after a few weeks when epithelium has usually covered the underlying tissue If following dry or moist skin necrosis granulation-tissue has grown over the exposed bone the wound area may be covered by pinch grafts

Exercises From the first day on, the toes should be actively moved through as wide a range of motion as possible In case of a peroneal nerve paralysis, a piece of foam rubber is placed between the toes and the toe plate of the cast, and small traction slings are applied to the toes for exercising them



2492 April 1, 1948 2492 a November 10 1948 2492 b, February 26, 1953

FIG 2492—*Open* comminution fracture of the middle thirds of left tibia and fibula Comminution of tibia for a length of 18 cm Sustained by a 25 year old unskilled construction worker who fell from the second floor 10 cm transverse lacerated wound in the center of the lower leg with torn muscle Proximal to that wound a 3 cm laceration 7 cm proximal and lateral two 1 cm long wounds caused by prongs of fragments piercing through the skin Treatment consisted of excision of all wounds removal of all torn parts of the muscles, insertion of two drains closure of the skin without tension Reduction by calcaneus pin traction of 5 kg in the screw traction apparatus Long leg cast which was split immediately Continuous traction of 2 kg in the cast When a superficial skin necrosis at the edge of the *wound had healed a long leg walking cast was applied 6 weeks after the accident*

FIG 2492 a—Same case 7 months later The first walking cast was removed after 5 months At that time the fracture showed a still springy resistance Another long leg walking cast was therefore, applied Bony union of the tibia followed Fracture cleft still open medially Shortening of 2 cm Non union of fibula

FIG 2492 b—Same case after 5 years No angulation Fracture cleft bridged by bone at the medial side of tibia Bony union of fibula Freely movable scars Full range of active motion of all joints Asymptomatic Patient resumed his previous work These roentgenograms are taken from a paper by Zrubecky

Further check roentgenograms are made every other week

Duration of Immobilization in the Split Cast and Incorporated Skeletal Traction If healing of the wound has been uneventful a long leg cast is applied after 4 weeks Application of the cast is delayed in the case of disturbed healing of the wound until the wound has healed completely or has, at least, become sufficiently small

Further Treatment of Open Fractures of the Shafts of the Tibia and Fibula in the Long Leg Walking Cast

Further treatment is carried out as in closed fractures of the shafts of the tibia and fibula (see pp 1724—1737)



2493 March 19 1933 2494 March 19 1933

FIG 2493 —*Open* triple flexion fracture of the lower leg Sustained by a 67 year old man who was knocked down by a car

FIG 2494 —Same case after wound excision reduction by screw traction and application of a transfixion cast with two pins incorporated Apparent perfect position of all fragments There is however a gap (diastasis) between the proximal and middle fragments

Origin, Avoidance, and Treatment of Early Complications Following Open Fractures of the Shafts of the Tibia and Fibula

Early complications following open fractures of the tibia and fibula may be 1 Death, 2 Amputation, 3 Progressive spreading infection, 4 Skin necrosis, 5 Circulatory disturbances, 6 Nerve lesions

Causes and Avoidance of Death Death from shock due to other concomitant severe injuries or death from pulmonary embolism is often unavoidable whereas death from pneumonia can usually be prevented if cooling of the patient is avoided Death from septicemia following progressive spreading infection can usually be avoided by accurate excision of the wound drainage skin closure without tension and uninterrupted immobilization

Amputation must be performed if the foot is pulseless and cold and becomes necrotic due to arterial rupture Amputation due to spreading infection and septicemia can be avoided by accurate wound excision, uninterrupted immobilization and omission of manipulative corrections in the first few weeks, and if, in infection, the abscesses are widely exposed and immobilization is kept up without interruption Antibiotics are valuable agents



2495, November 18 1933 2496, September 12 1934

FIG 2495 —Same case 8 months later All wounds healed without infection On the 24th day however infection flared up at the proximal pin site because the cast had extended up to the knee only Bony union followed with satisfactory alignment Ring sequestrum at the proximal pin site

FIG 2496 —Same case 18 months after the accident Firm bony union Ring sequestrum has been cast off No fistula

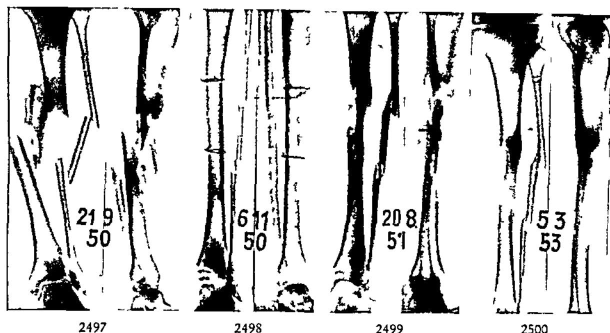
Spreading infection can be avoided in the same way as amputation due to infection

Skin necrosis, frequently causing infection of the deep layers, can usually be avoided by excision of the severely soiled and devitalized skin, and by subsequent plastic repair of the skin

Blood vessels and nerve damage due to direct trauma or severance are unavoidable consequences of the injury Those due to constricting bandaging can, however, be avoided by proper bandaging technique, by completely splitting every cast throughout its full length, and by carefully observing the patient and his affected limb

Origin, Avoidance, and Treatment of Late Complications Following Open Fractures of the Tibia and Fibula

Late complications following open fractures of the tibia and fibula are 1 Angulation, shortening, and rotary displacement, 2 Delayed callus formation and non-union, 3 Sinus formation and sequestra, 4 Ulcers, 5 Dystrophic



2497 2498 2499 2500

Fig 2497—*Open* double fracture of left tibia and fibula in a 53 year old fireman who was knocked down from his motorcycle by a jeep on September 21 1950 The fragments are no exposed in the 12 cm long wound on the posteromedial aspect of the lower leg 2 cm long wound on the anterior side of the medial fragment Treatment Accurate excision of the wound under spinal anesthesia Subperiostal exposure of the fragments for the application of two wire loops insertion of two drains suture of the skin calcaneus pin long leg cast which was split immediatley for 46 days From the 6th day on necrosis of the skin at first dry la er moist No fever Slow development of secondary infection of the bone Wire removed on 98th day sequestrectomy on 228th day Long leg cast for a total of 493 days osseous union of fragments after 539 days In hospital for 210 days out patient treatment 471 days Total duration of sick leave 681 days

Fig 2498—Same case at time of cast change 6 weeks later Very satisfactory position of fragments

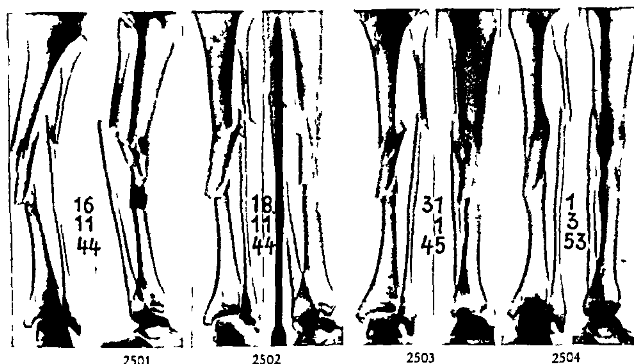
Fig 2499—Same case at sequestrectomy after 11 months

Fig 2500—Same case after 2½ years Bony union Good alignment in both projections Shortening of 4 5 cm At times a sinus re opened Dimpled scar adherent to bone Toe motion limited by 50/ Only shaky movements of subtalar joint Range of ankle joint 85° to 110° as compared to 70° to 120° on the uninjured side Knee motion 165° to 120° compared with 175° to 45° on the uninjured side Pain when walking At present we would use medullary wires in so severely displaced a fracture (figs 2458—2463) The fragments need not be exposed and there is little risk of skin necrosis

disturbances (muscle atrophy, demineralization, edema, cyanosis, claw toes, and pes cavus), 6 Arthrosis, 7 Pain and limitation of movements

Angulation, shortening, and rotary displacement can be avoided by adequate reduction and uninterrupted maintenance of the acquired good position of the fragments (figs 2486—2489, 2492—2496 2501—2504)

Delayed callus formation (figs 2497—2500) and *non-union* can be avoided if bone splinters still connected with the periosteum are not removed, if fragments are not pulled apart by excessive traction (figs 2418—2425), if osteosynthesis by firm wire sutures or metal bands (figs 2470—2476) is avoided, and if medullary nails or plates and screws are not used



2501 2502 2503 2504

Fig 2501—*Open* double fracture of left tibia and fibula in a 50 year old correspondent who was knocked down by an automobile She sustained a 2 cm long wound at the anterolateral side of the proximal fracture site Treatment Local anesthesia Steinmann pin through the calcaneus excision of the wound insertion of a drain suture of the skin long leg cast applied in the screw traction apparatus under traction of 5 kg immediate splitting of the cast continuous calcaneus pin traction of 3 kg for 25 days and of 2 kg for 5 days followed by a long leg walking cast for 46 days From the 8th week on she could walk without pain without the help of a cane

Fig 2502—Same case 2 days later Straight axes of the two main fragments Oblique position of the two intermediate fragments

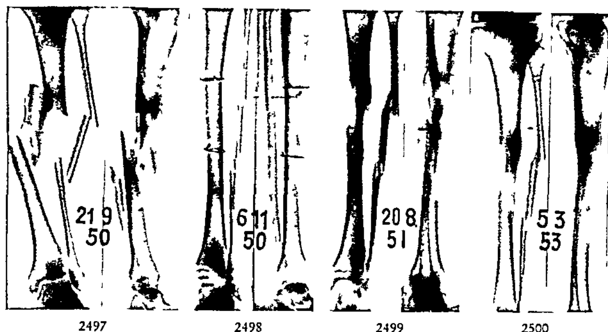
Fig 2503—Same case on removal of the cast 76 days after the accident Bony union with 5° varus between the main fragments moderate decalcification at the lower end of tibia Unna s paste boot Bony union occurred so soon because a shortening of 8 mm was maintained at reduction For reasons related to the war she did not resume work until six months after the accident

Fig 2504—Same case after 8½ years Firm bony union of the fracture sites No arthrotic changes of the ankle joint Asymptomatic Normal gait Free range of active motion at all joints (Figs 2497—2504 have been taken from Hamilton s and Jahna s paper [1])

The *formation of sinuses or sequestra* can be prevented by avoidance of infection following osteosynthesis (figs 2477—2480, 2497—2500) and by avoidance of forceful attempts at delayed manipulative reduction (figs 2505 to 2508) If sinuses have formed they can be brought to close in most but unfortunately not in all cases, by sequestrectomy (figs 2505—2508)

Ulcers can usually be prevented if necrosis of the skin is avoided by adequate skin grafting and wound closure without tension No undue pressure must be exerted on damaged skin Skin necroses over the medial surface of the tibia cause adherent scars which tend to break down In some cases they can be covered by pedicle grafts from the uninjured leg

[1] Hamilton and Jahna American J Surg *88* 218—225 1954



2497 2498 2499 2500

FIG 2497—*Open* double fracture of left tibia and fibula in a 53 year old fireman who was knocked down from his motorcycle by a jeep on September 21 1950 The fragments are not exposed in the 12 cm long wound on the posteromedial aspect of the lower leg 2 cm long wound on the anterior side of the medial fragment Treatment Accurate excision of the wound under spinal anesthesia Subperiostal exposure of the fragments for the application of two wire loops insertion of two drains suture of the skin calcaneus pin long leg cast which was split immediatley for 46 days From the 6th day on necrosis of the skin at first dry, la er moist No fever Slow development of secondary infection of the bone Wire removed on 98th day sequestrectomy on 228th day Long leg cast for a total of 493 days osseous union of fragments after 539 days In hospital for 210 days out patient treatment 471 days Total duration of sick leave 681 days

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the injured leg of the toes, the talocrural, and the subtalar joints and noted the degrees of the angles?
5 Have I cautiously tested passive motion of the knee and the hip in the injured lower limb in order not to overlook concomitant fractures and dislocations of the hip?
6 Have I tested sensibility in case of motor paralysis?
7 Have I measured the size of the wound?
8 Have I answered the questions 1 to 31 (p 1715) for closed fractures of the tibia and fibula, namely treatment of shock, local anesthesia, roentgenograms, ordering the necessary equipment, checking the equipment, insertion of the calcaneus pin?
9 Have I given Penicillin before excision of the wound?
10 Have I amputated the leg if rupture of vessels and nerves was encountered at wound excision and if the foot has remained pulseless, cold and pale after reduction?
11 Have I amputated the leg if nerves and vessels have been preserved but more than half the length of the leg's skin tube was missing, and if the soft tissues have been badly lacerated?
12 Have I excised a wound only within the first 24 hours and only in absence of a purulent discharge?
13 Have I enlarged the wound by sufficiently long longitudinal incisions in order to get a good survey of wound cavities and wound pockets?
14 Have I refrained from transverse incisions when enlarging the wound?
15 Have I excised only 1 to 2 mm of the wound edges if the skin was normal?
16 Have I removed all foreign bodies and all torn and devitalized tissue?
17 Have I excised so much from the proximal and distal muscle stumps that spurting vessels have become visible?
18 Have I left in place bone splinters which have remained in contact with the surrounding tissue as their removal may result in defect non-union?
19 Have I only clamped vessels but not ligated them in order to avoid thread fistulae?
20 Have I refrained from suturing torn muscles, tendons and fascia in order to avoid foreign body reaction and sinus formation?
21 Have I sutured torn nerves?
22 Have I inserted 1 to 3 drains and led them out at the most dependent point of the wound cavity and not through the wound?
23 Have I not led the drain through the interosseous space or through the calf?
24 Have I stitched the drains to the skin?
25 Have I, after accurate wound excision, reduced the fragments in the open wound?
26 Have I inserted medullary wires for immobilizing severely displaced transverse fractures and unstable fractures (figs 2458—2466)?
27 Have I applied a loose wire suture (fig 2487) in severely displaced short oblique fractures?
28 Have I applied a loose wire loop (figs 2467—2469) in severely displaced long torsion fractures?

Dystrophic disturbances with muscle atrophy, demineralization, edema, cyanosis, claw toes, and pes cavus (figs 2490, 2491) can usually be avoided if infection and excessive traction are ruled out In circulatory failure due to extensive rupture of soft tissue and vessels, distrophic disturbances may occur, but not as severe as shown in figure 2490, if excessively heavy and prolonged traction is avoided This is also true *for arthrosis, pain, and limitation of* movements

Arthrosis Zrubecky re examined 202 patients of our 461 cases of open fractures of the tibia and fibula In these 202 patients, roentgenograms of the talocrural and subtalar joints of both feet were made, the skin temperature was taken *with Heidenwolff s skin thermometer*, and oscillometric measurements were taken, 2 to 25 years after the injury The punched-card I B M system was used to evaluate the end results He found that arthrosis is due to circulatory damage

Of the 202 re examined patients,

83 (41 1%)	(67 8%)	had no arthrosis,
54 (26 7%)		had traces of arthrosis,
44 (21 8%)	(32 2%)	had slight signs of arthrosis,
18 (8 9%)		had moderate arthrosis,
2 (1 0%)		had severe arthrosis,
1 (0 5%)		had ankylosis

As *direct* proof for the occurrence of circulatory disturbances he cites that oscillometric measurements were decreased in only 11 63% of the patients without arthrosis but were decreased in 40% of the patients with medium and severe arthrosis

He finds as *indirect* proof that the occurrence of arthrosis was dependent on the condition of the circulation, size and severity of the soft tissue injury, *kind of wound healing, the site of the fracture, primary lateral displacement* post-reduction lateral displacement, angulation, shortening, distraction, traction weights, duration of continuous traction, age of the patient, and the period of time elapsed since the accident

Pain in Arthrosis Though most patients with arthrotic changes had no pain, many of those with edema of the ankle region complained of pain This is important for disability evaluation

Questions We Should Ask Ourselves in Order to Avoid Failures in Fresh Open Fractures of the Tibia and Fibula

For general examination the same questions apply as in dislocations of the hip (Vol II/p 1088), namely, shock color and facial expression pulse, blood pressure, reflexes, active mobility, etc The following questions should be added

1 Have I observed the shape and abnormal mobility of the lower leg?
2 Have I observed the color of the foot (pale, mottled, cyanotic, or normal)?
3 Have I checked the dorsalis pedis and posterior tibial pulses of both feet?
4 Have I tested the active motion of all joints in the uninjured leg starting with the toes and going up to the hip? Have I tested the active motion in

48 Have I immediately decreased the longitudinal traction when the lateral displacement has been corrected?
49 Have I avoided valgus and antecurvature to prevent tension of the skin which is so often damaged at the anteromedial side?
50 Have I moved the rod holding the suspension sling slightly laterally to correct a valgus deformity?
51 Have I slightly raised the knee suspension sling or the longitudinal traction to correct antecurvation?
52 Has the leg been examined by fluoroscopy in both main projections?
53 Have I made roentgenograms in both projections if fluoroscopy showed satisfactory position of the fragments?
54 Have I performed renewed reduction by increasing the longitudinal traction if the roentgenograms showed lateral displacement of the tibia by more than a third of the width of the shaft?
55 *Have I refrained from performing more than two attempts at reduction, to avoid infection?*
56 Have I applied a few strokes of mastisol (skin adherent) to the skin and placed the 5×70 cm incised flannel strip wrinkle-free on the middle or proximal third of the thigh so that both ends cross at the lateral and not the anterior aspect?
57 Have I applied the posterior plaster splint in such a way that it does not reach beyond the flannel strip where it could damage the skin?
58 Have I turned back the flannel strip prior to application of the last plaster bandage so that the upper edge of the cast becomes smooth and does not damage the skin?
59 Have I very carefully applied the plaster bandages around the pin sites, and re-inforced the cast by 8-layer pieces of plaster bandage, 4×4 cm in size and perforated in the center
60 Have I applied a long leg cast and not a lower leg cast as the latter would not allow sufficient support?
61 Has fluoroscopy been briefly done and angulation corrected while the cast is still soft?
62 Have I made roentgenograms in both projections when the cast has set?
63 Have I placed the encased leg on an oblique splint with pulley attached, and applied traction of 5—6 Kg (fig 2485 a)?
64 **Have I split the cast throughout its full length and cut the windows before the patient has left the plaster room?**
65 Have I kept the windows small enough? the margin round the wound should not be more than 10 to 15 mm lest the fragments be displaced into too large windows and press on damaged skin
66 Have I replaced the removed piece of plaster to avoid a hematoma?
67 Have I cut out the cast at the toes, cleansed the toes, and cleared the cast of plaster particles with a vacuum cleaner?
68 Has the cast been inscribed properly (dates of accident, wound excision, reduction, application of the cast, day and hour of the planned removal of the cast, and of the next roentgen check, name of the doctor)?
69 Has the pre reduction roentgenogram been sketched on the cast?

29 Have I *refrained from osteosynthesis in stable fractures with little displacement?*

30 Have I refrained from osteosynthesis by (1) medullary nails (2) firm wire loops, (3) metal bands, (4) firm transverse or longitudinal wire suture, or (5) plates and screws?

31 Have I, after accurate excision of the wound, sutured, without tension the skin and only the skin, and buried no ligatures or deep sutures with exception of nerve sutures?

32 Have I *performed one or two longitudinal relaxation incisions 5 to 7 cm* distant from the wound in tension, or skin defects? Have I covered the fractured bone by sliding flaps and not by dermatome or pinch grafts?

33 Have I covered the resulting new superficial skin defect with a dermatome graft (*fig* 2486) *or pinch grafts* (*fig* 2489, 2490) *immediately, or after* 5 to 6 days?

34 **Have I sutured wounds only if they had been accurately excised within the first 12 to 24 hours? If foreign bodies or lacerated tissue are left in the wound, *severe infections, e g, gas gangrene, tetanus and spreading* cellulitis may develop in spite of all antibiotics**

35 Have I covered the wound with no more than a 2 to 3 cm wide 8 layer sterile gauze sponge moistened with Peruvian balsam? The fragments might become displaced in the cast if large thick sponges were used

36 Have I placed the sterile hemp cord from the toes up to the inguinal fossa and fixed it with a sterile bandage in the wound area?

37 Have I applied a traction bandage to the well foot?

38 Have I placed the patient on the long screw traction apparatus (fig 2348) for applying the long leg cast?

39 Have I fixed the uninjured leg to the traction screw with the traction bandage, and the injured leg to its traction screw with the rotating stirrup of the calcaneus pin?

40 Have I inserted a spring scale between the rotating stirrup and the hook of the traction screw?

41 Have I walked around the patient to confirm that both legs have been positioned symmetrically?

42 Have I inserted a 0 5×12×18 cm pad in the popliteal fossa and suspended the extended leg at the knee with a 10 cm wide calico bandage with tongue blades incorporated as stays

43 Have I kept apart the two limbs of the calico bandage by a 2×10×25 cm wooden spreader to avoid pressure on the bone?

44 Have I reduced those fractures which have not been treated by medullary wires or a loose wire suture or a loose wire loop by 5 to 8 kg calcaneus pin traction?

45 Have I obtained roentgenograms in both main projections *to confirm* the result of reduction and to exclude an interfragmentary gap (diastasis)?

46 Have I decreased the traction weights in diastasis?

47 Have I, in lateral displacement temporarily increased the longitudinal traction in order to make apposition of the fracture ends possible?

wound has already become septic it should be treated according to the rules given in Vol I/pp 181—198, i e, (1) either by relieving the tension through removing the skin sutures and subsequent uninterrupted immobilization, or by operative exposure of the infected foci and subsequent uninterrupted immobilization, (2) by avoidance of mechanical or chemical disturbances, and (3) by administration of antibiotics

In open fractures of the tibia and fibula, operated upon immediately after the injury, the post operative swelling and fever, as a rule, subside after one week Should, however, infection set in with reddening, increased swelling, fever, and pain, in spite of (1) accurate wound excision, (2) closure of the skin without tension, and (3) administration of penicillin, some sutures must be removed to relieve tension Infection will then subside in many cases In all infection cases a smear should be taken and the organisms tested for sensitivity to antibiotics If suppuration has set in, the window in the cast is enlarged to allow for easy discharge of the pus The wound should not be irrigated with antiseptics in order to avoid disturbances described in Vol I/pp 169, 188 The more the wound is left undisturbed the less the discharge will be The wound remains without dressing When the fever has subsided, crusts on the wound are removed only every second or third week (see Vol I/p 184)

Operative exposure of the fracture site in the first few days is necessary only in cases of a spreading or anaerobic infection, or if the inguinal glands become markedly swelled in spite of removal of the skin sutures Deep incisions must then be made under general anesthesia and under tourniquet control All wound cavities and pockets must be exposed One or more drains are inserted in the wound and led out through 4 to 5 cm counter incisions Drains must never be led out through the interosseous space, the calf, or transversely through the lower leg, in order to avoid erosion of a vessel Bone splinters still connected to surrounding tissue must be retained to avoid defect pseudarthrosis (figs 2606—2608) The fever usually subsides within 2 to 4 days following wide exposure of the infectious foci and uninterrupted immobilization Should the fever last for a longer period and should much pus, on pressure, discharge from a pocket, another incision should be made Among our 461 open fractures of the tibia and fibula a second incision was necessary in only 14 cases

Reduction and Immobilization of Infected Fractures of the Shafts of the Tibia and Fibula in a Split and Fenestrated Long Leg Cast Slight angulation or rotation is corrected whether an incision has been necessary or not Lateral displacement or shortening must not be corrected with force After insertion of a calcaneus pin a long leg cast is applied as described on pages 1724, 1725, split throughout its full length, and fenestrated The plaster cast must in all cases reach up to the thigh (fig 2485 a) A lower leg cast does not provide sufficient immobilization When the infection has subsided, a closed cast may be applied

Contraindication to Reduction in the Screw Traction Apparatus Shortening and lateral displacement in infected fractures of the tibia and fibula must never be corrected forcefully manually or in the screw traction apparatus This might cause severe infection as has been mentioned in

70 Have I suspended the foot to counteract torsion?
71 Have I attached two U-supports to support the blanket?
72 Has the patient been put in a pre-warmed bed after the two U-supports have been attached?
73 Have I fastened the splint to the lower end of the bed?
74 Have I provided a wooden box for the uninjured foot?
75 Have I raised the lower end of the bed by 30 cm?
76 Have I dried the cast with radiant heat?
77 Have I applied traction of 5 to 6 kg in non operated fractures?

The following questions should be asked for *further treatment*

78 Have I daily checked the patient's general condition?
79 Have both his legs been uncovered at daily round?
80 Have I daily checked the patient's temperature and pulse?
81 Have I daily checked the amount of traction, 5 to 6 kg in nonoperated fractures?
82 Have I obtained roentgenograms in both projections on the second day to exclude diastasis?
83 Have I immediately decreased the traction weight in the presence of diastasis?
84 Have I exposed the wounds the day after the injury for "treatment without dressing"?
85 Have I removed the drain and covered the small wound with a sponge moistened with Peruvian balsam?
86 Have I, in the presence of fever, removed sutures only if reddening and marked swelling of the wound region and of the inguinal glands have occurred?
87 Have I refrained from forcefully correcting lateral displacement manually or in the screw traction apparatus in the first few weeks as this may cause severe infection?
88 Have I, when the swelling has subsided, closed the split cast with bandages within the first few weeks?
89 Have I refrained from removing dry necrotic skin?
90 Has the patient actively moved his toes daily?
91 Have I placed foam rubber under the toes in peroneal paralysis?
92 Have I made check roentgenograms every other week?
93 Have I, after the wound has healed without complication, applied a long leg walking cast after four weeks and then continued treatment as for closed fractures of the tibia and fibula (see pp 1724—1737)?

97 INFECTED FRACTURES OF THE TIBIAL AND FIBULAR SHAFTS

If an open fracture of the tibia and fibula is admitted for treatment as late as 8 to 10 hours after the injury and the wounds already show a purulent exudate, they must no longer be subjected to thorough excision and must under no circumstances be closed by sutures not even when using antibiotics Soiled and torn tissue and all foreign bodies should, however be removed The wound must remain *wide open* in order to avoid tension If the



2509 December 10 1934 2510 February 4 1935



2511 April 3 1935 2512 July 15 1935

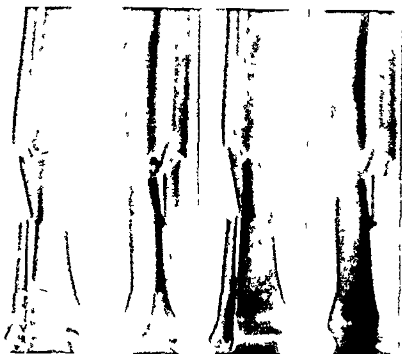
Fig 2509 – Draining non union of tibia following a fracture of the tibia treated at another hospital Sustained by a 36 year old lumberman who was hit by a falling tree Varus and recurvation of 15° each

Fig 2510 – Same case 2 months after open osteotomy of the fibula and correction of the angulation The fibular fragments which now override by 1 5 cm allow the tibial fragments to approximate

Fig 2511 – Same case after 2 months Beginning bony union

Fig 2512 – Same case after 5 months Bony union with good alignment Satisfactory density of bone Sinus has closed

Vol I/p 160 and on page 1781 In shortening, continuous traction of 6 Kg is exerted at the calcaneus pin after application of the long leg cast In cases without shortening, continuous traction should be exerted with 3 to 4 Kg to prevent shortening and angulation



2505 September 7 1936 2506 September 8 1936



2507 December 2 1936 2508 May 5 1937

Fig 2505 —Three month old infected fracture of the tibia and fibula with big ring shaped sequestrum Sustained by a 40 year old shop assistant who while on a motorcycle collided with an automobile After excision the wound healed without complication 14 days later the position of fragments was corrected at another hospital High fever and infection followed

Fig 2506 —Condition after sequestrectomy

Fig 2507 —Three months later satisfactory callus formation

Fig 2508 —Eleven months after the injury bony union in good alignment

to approach each other prior to consolidation of the fibula In general, it is feasible to wait for roentgenographic evidence that the sequestrum has loosened Cortical sequestra, as opposed to living bone splinters, usually show increased density It usually takes 3—6 months until sequestra separate Massive sequestra as shown in M N/figs 511—526 must not be removed before an involucrum has formed A long leg walking cast may be applied in the meantime

Roentgen Examination of the Draining Sinus before Sequestrectomy In order to confirm position and extent of the fistulous passages roentgenographically they are filled with a radio opaque contrast medium

Technique of Sequestrectomy Before the operation, wound pus should by sent to a laboratory for testing its sensitivity to various antibiotics The night and morning before the operation and after the operation the antibiotic of choice is administered The operation is performed under general or spinal anesthesia A tourniquet is applied as fistulous openings and draining sinuses can only be traced properly in a bloodless field The bone is exposed by a longitudinal incision, the scars are not excised Especially on the anterior side of the tibia all loss of skin must be avoided All fistulous passages are traced, laid open wide, and covered with muscles if these are within easy reach The wound is then firmly packed and the tourniquet is removed If the packing is removed 5 minutes later bleeding has usually stopped No vessels must be tied and no deep sutures buried in the depth of the wound as ligatures often cause prolonged draining sinuses The skin is closed with sutures except for the primary fistulous opening A compression bandage is applied The wound cavity fills with blood and will often heal under a dry crust For a period of time we filled the wound with vaseline, according to Orr Packing or irrigating the bone cavity delays the healing or prevents it because the walls of the wound cavity become thickened with scars and can no longer collapse With the help of the above described treatment we reduced the number of draining sinuses among our 394 open fractures of the shafts of tibia and fibula, to only 3 (0 7%) when we discharged the patients from the hospital At re examination, one of these sinuses had closed so that only 2 (0 4%) patients with sinuses remained

Questions We Should Ask Ourselves in Order to Avoid Failures in the Treatment of Infected Fractures of the Shafts of the Tibia and Fibula

1 Have I refrained from excision and suture of septic wounds?
2 Have I removed soiled and torn tissue and all foreign bodies, and have I left the wound wide open to avoid tension?
3 Have I treated septic wounds according to rules given in Vol I/pp 181 to 198?
4 Have I relieved tension by removal of the sutures and operative exposure of the infected foci? Has immobilization been uninterrupted and have antibiotics been used?
5 Has a swab of the wound secretion been taken for examination of the sensitivity to antibiotics?

Duration of Immobilization According to the size of wounds, or the comminution of bones, the cast is retained for 3—6 months and in some cases even longer

Repair of Skin Defects In a skin defect as shown in fig 2489 compresses soaked in camomile flower tea, saline or boric acid solution are administered alternately until the wounds show fresh and red granulation tissue Then, a new cast is applied and a window cut over the wound The wounds are covered by split grafts (fig 2486) or pinch grafts (fig 2489 b) The latter should not be placed so close to each other as in fresh wounds (figs 157—158 c, 1501—1505) A gauze veil is glued over the grafted area The grafts usually take within 10 to 12 days (fig 2489 b)

Treatment of Infected Fractures of the Tibia and Fibula in Traction During World War I we treated almost all open fractures of the tibia and fibula solely by continuous traction, i e, without a cast and without a dressing (figs 2483, 2484) At present, we apply a fenestrated long leg cast in all infected fractures Posterior bowing (recurvation) of varying degree develops, as a rule, in a cast When this occurs and, if the temperature has been normal for at least two weeks, the cast is removed and the leg is placed on a well bandaged lower leg splint (see p 1711) The fore foot suspension is lowered adequately (fig 2484) *Thus, angulation becomes corrected at once or within* a few days If after 5 to 6 weeks, a certain degree of consolidation is already present, a rubber cushion is placed under the fracture site to correct the recurvation The foot sinks by its own weight and consequently abolishes the angulation The leg should not be straightened forcefully Calcaneus pin traction must not exceed 1 to 2 kg For exposed wound treatment a small window is cut out of the bandage which covers the splint to allow for discharge of the pus Big windows would cause a window edema as shown in figure 2483 The edges of the window are lined with watertight dressing, and covered with sponges and zinc paste If the bandages become moist from wound secretions, boric acid powder is sprinkled on for drying and combatting the foul smell If crusts form on the wound they should not be removed but be left in place for 2 to 4 weeks

Sequestrectomy If the skin becomes necrotic and infection occurs, the fragments become exposed to a smaller or larger extent Splinters which are not loose should not be removed as they are usually connected to the periosteum If they are left alone, only a small superficial lamella 1 to 2 mm thick (M N/fig 514) will as a rule be cast off If they are removed too soon, either deep layers of bone become exposed and cast off or periosteum becomes exposed and perishes If the tibial crest is exposed sequestration of a superficial lamella may take 4—8 months Small bone splinters and superficial lamellae which have come off can be removed with a forceps Deep sequestra and those lying in the medullary space — as often seen following osteosynthesis especially medullary nailing (M N/figs 219, 511—526 864 to 873) — can be removed only by open operation

Time of Sequestrectomy Loose sequestra may be extracted from the wound at any time If a big sequestrum lies between the main fragments as in figure 2505, it should be removed as soon as possible to allow the fracture ends

27 Have I placed the pinch grafts wider apart from each other than in the repair of fresh wounds so that they will not be lifted by wound secretion?
28 Have I, when a posterior bowing occurred in the cast after the swelling of the calf had subsided, removed the cast — provided the patient had been without fever for at least 2 weeks — and continued treatment with traction on a well bandaged lower leg splint as described on page 1711?
29 Have I in such a case weighted the traction with only 1—2 kg and lowered the foot suspension?
30 Have I placed a rubber cushion under the fracture site to correct posterior bowing if a fracture is 5 to 6 weeks old and has consolidated to some extent?
31 Have I refrained from forceful attempts to correct posterior bowing?
32 Have I cut a small window out of the bandage covering the splint to allow for evacuation of pus?
33 Have I made the window as small as possible to avoid window edema?
34 Have I covered the edges of the cast surrounding this window with watertight fabric, and have I put on swabs and zinc paste and sprinkled boric acid powder to avoid foul smell and moisture?
35 Have I removed, with a forceps, small sequestra and loose superficial bone lamellae, but left those connected with the periosteum?
36 Have I removed by operation deep sequestra and medullary sequestra if they show increased density in the roentgenogram?
37 Have I removed sequestra lying between the main fragments as soon as possible to allow the fragments to approach each other before the fibula becomes firm?
38 Have I removed a massive sequestrum only after an involucrum has formed and have I applied a long leg walking cast for the meantime?
39 Have I tested the sensitivity of the organisms to various antibiotics, prior to sequestrectomy?
40 Have I given the antibiotic which proved the most effective the night and the morning before the operation, and have I continued its administration postoperatively?
41 Have I, prior to sequestrectomy, filled the discharging sinus with a contrast medium and obtained roentgenograms in both main projections?
42 Have I performed sequestrectomy under general or spinal anesthesia and in a bloodless field in order to be able to trace the fistulous tracts properly?
43 Have I exposed the bone through a longitudinal incision without excising scars?
44 Have I accurately traced the fistulae and laid them open wide?
45 Have I placed muscles into these new wounds if they are within easy reach?
46 Have I refrained from burying deep sutures and ligatures to avoid formation of chronic discharging sinuses? Have I packed the wound for 5 minutes before removing the tourniquet?
47 Have I sutured the skin but left open the original fistulous opening?
48 Have I applied a compression bandage?

6 Have I, in fresh cases of open fractures of the tibia and fibula which had become septic, in spite of the treatment carried out as described on pages 1771—1783, removed the sutures and enlarged the window in the cast to allow for discharge of the pus?
7 Have I refrained from irrigating the wound with antiseptic solutions?
8 Have I exposed the wound and treated it without a dressing?
9 Have I operatively exposed the fracture site within the first few days only in a case of progressive or anaerobic infection?
10 Have I performed the operation under a general anesthetic and under a tourniquet? Have incisions been made reaching deep into the sound tissue?
11 Have I laid open all wound cavities and pockets and inserted one or more drains?
12 Have I led out the drains through new incisions 4 to 5 cm long?
13 Have I refrained from leading out the drains through the interosseous space, the calf, or, transversely, through the lower leg, in order to avoid erosion hemorrhage?
14 Have I left alone bone splinters which are still connected with the surrounding tissue, in order to avoid a defect pseudarthrosis?
15 Have I operated again if the temperature remained elevated and if much pus could be expressed from a pocket?
16 Have also I, in infected fractures of the shafts of tibia and fibula, corrected a slight angulation and rotation before application of the immobilizing full leg cast?
17 Have I left alone lateral displacement and shortening in infected fractures of the shafts of tibia and fibula and refrained from forceful correction?
18 Have I inserted a calcaneus pin and applied a full leg cast as described on pages 1724, 1725? Have I answered the questions 57—61 given on page 1791?
19 Have I split the cast throughout its full length and cut a window before the patient left the plaster room?
20 Have I refrained from reduction in the screw traction apparatus in order to avoid severe infection (see Vol I/p 160, and p 1781)?
21 Have I, after application of the long leg cast weighted the calcaneus pin traction with 6 Kg in the case of severe shortening and with 3 to 4 Kg in all other cases so as to avoid shortening and angulation?
22 Have I applied a closed long leg cast after the acute inflammation subsided?
23 Have I retained the cast for 3 to 6 months or even longer, depending on the size of the wounds and the state of the fracture healing?
24 Have I removed wound crusts only every 2 or 3 weeks after the fever had subsided?
25 Have I treated skin defects with compresses soaked in camomile-flower tea, saline, or boric acid solution until the wound showed fresh granulation?
26 Have I then applied a new cast, cut windows over the wounds, and covered the wounds with dermatome or pinch grafts?

2 (0 4%) for concomitant injuries of the ipsilateral leg
14 (2 8%) patients had amputations later, namely,
2 patients (on the 6th and 149th day) due to arteriosclerotic gangrene of the foot,
3 patients (on the 2nd, 9th, and 14th day) due to gas gangrene,
7 patients (on the 6th, 9th, 39th, 40th, 109th, 770th day and after 9 years) due to infection or extensive necrosis of skin or muscles,
1 patient (on the 360th day) due to a pre existing osteomyelitis

Healing of the Wounds

Without event	342 cases (78 4%)
Mild complications	26 cases (6 0%)
Severe complications	68 cases (15 6%)

Grouping 1 Without event Wound healing without skin necrosis, without discharge, without sequestrum formation 2 Mild complications Necrosis of the skin with or without exposure of the bone, discharge from the wound, but without the need of an incision or a sequestrectomy 3 Severe complications Cases requiring operation under general anesthesia such as an incision or sequestrectomy

If all patients who were treated conservatively (i e, by traction and plaster alone, or transfixion) are taken together in one group and all patients who were treated by open operation (i e, primary osteosynthesis or primary medullary nailing) are taken into another group, the results of wound healing are as follows

355 cases treated conservatively, 284 cases without complication (80%),
39 cases treated by primary osteosynthesis, 31 cases without complication (79 5%),
42 cases treated by primary medullary nailing, 24 cases without complication (64 3%)

Of the fractures of the lower leg treated by medullary nailing only 64 3% of the cases healed without complication, whereas 79 9% of the cases treated conservatively or by primary osteosynthesis healed without complication This shows that medullary nailing causes most of the wound complications, whereas the results after conservative treatment and after primary osteosynthesis do not differ much (0 5%)

Distraction (Excessive Traction) and Wound Complication Of the 73 cases with distraction, 53 (72 6%) healed without wound complication, whereas 20 (27 4%) had complications Thus the percentage of complications is about 8% higher in the cases with excessive traction

Sequestrum Formation Sequestra formed in 43 cases (10 9%) Small sequestra separated and could be removed with the forceps in 22 patients (5 5%) A sequestrectomy under general anesthesia was necessary in 21 patients (5 2%)

Hospitalization The patients (with exception of those with medullary nailing) were hospitalized for an average of 72 days, patients treated with traction and plaster for 71 8 days with plaster alone for 52 8 days, with

49 Have I neither packed nor irrigated bone cavities to avoid thick callous scars?

End-results of 506 Fresh Open Fractures of the Tibia and Fibula

In the 25 years from December 1925 to December 1950, 506 fresh open fractures of the shafts of tibia and fibula were treated in 500 patients at the Vienna Accident Hospital Among these cases were 377 (75 4%) insured industrial accidents

Krosl[1] surveyed 45 open fractures of the shafts of the tibia and fibula which were treated by medullary nailing Zrubecky[2] surveyed the remaining 461 cases All 506 cases were evaluated with the I B M punch card system

Ehalt[3] described our first 163 cases in his book, including the open fractures at the upper and lower end of the lower leg Zrubecky re-examined Ehalt's cases 15 years later I[4] reported on the end-results of all these cases at the Congress of the German Surgeons in 1953

Type of Treatment If deaths and cases with primary or secondary amputation are excluded, 436 cases of tibiofibular shaft fractures remain The treatment following accurate wound excision and suture of the skin was as follows

1 Plaster cast alone 87 cases (19 95%)
2 Plaster cast with simultaneous skeletal traction (by means of an Steinmann pin or a calcaneus clamp) and subsequent long leg walking cast 232 cases (53 2 %)
3 Transfixion 36 cases (8 25%)
4 Medullary nailing 42 cases (9 4 %)
5 Other kinds of osteosynthesis (7 cases treated with longitudinal wire sutures, 11 cases with tight circular wire sutures 20 cases with loose wire sutures, 1 case with crossed Steinmann pins) 39 cases (8 9 %)

Deaths Of the 500 patients, 24 (4 9%) died while still in hospital 20 of these died on account of associated injuries Four patients (0 8%) died as the result of the fracture of the lower leg i e, two (0 4%) from embolism (on the third and the nineteenth day), two from infection (on the ninth and ninety-second day) one during secondary amputation on the ninth day No of the tibia and fibula, 45 patients (8 9%) were amputated

Amputations Of the 500 patients with 506 open fractures of the shafts of the tibia and fibula, 45 patients (8 9%) had amputations

31 (6 2%) patients had amputations immediately after the accident, viz
29 (5 8%) for fracture of the lower leg,

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[1] Krösl W Behandlungsergebnisse von 45 markgenagelten offenen Unterschenkelschaftbrüchen 54 Heft zur Unfallheilk 1956

[2] Zrubecky Behandlungsergebnisse von 461 offenen Unterschenkelschaftbruchen 54 Heft zur Unfallheilk 1956

[3] Ehalt W Behandlung der offenen Bruche der langen Rohrenknochen Maudrich Wien 1938 Tratamiento de las fracturas abiertas Labor Barcelona 1940

[4] Böhler L Unterschenkelschaftbruche Langenbeck s Archiv u Dtsch Ztschr f Chir 276 193—216 1953

Consolidation Period in Cases of Distraction Distraction occurred during treatment in 73 cases (18 5%) The average consolidation period of these fractures amounted to 179 05 days, of those without distraction 116 8 days

Cases with gaping fracture ends were counted among the non distracted fractures if the diastasis was due to serration of the fracture ends (38 cases — 9 6%), lateral displacement (13 cases — 3 3%) or displacement of a bending wedge (9 cases — 2 3%)

Secondary Operations Due to Delayed Callus Formation Among 436 cases a secondary operation was performed in 33 cases (7 6%) on account of delayed callus formation, namely

23 times (6 8%) among the 355 cases treated by conservative methods,
5 times (12 8%) among the 39 cases treated with primary osteosynthesis,
5 times (11 9%) among the 42 cases treated with primary medullary nailing

This shows that twice as many secondary operations for delayed callus formation were necessary in cases of primary osteosynthesis (including medullary nailing) than were necessary in cases treated by conservative means

Angulation Among 436 fractures (excepting deaths, primary and secondary amputations)

380 (87 15%) healed without angulation,
46 (10 55%) healed with angulation of between 6° and 10°,
8 (1 8 %) healed with angulation of 11° to 15°,
2 (0 45%) healed with angulation of 16° to 20°

Shortening, as shown in the roentgenogram, at the end of the treatment

393 (90 2%) cases had shortening of from 0 to 10 mm
13 (3 0%) cases had shortening of from 11 to 15 mm
13 (3 0%) cases had shortening of from 16 to 20 mm
9 (2 1%) cases had shortening of from 21 to 25 mm
3 (0 7%) cases had shortening of from 26 to 30 mm
5 (1 1%) cases had shortening of more then 30 mm

The severest shortening was 40 mm in a patient who was admitted with a gunshot fracture during the last days of the fighting on 1945 Her first roentgenograms could not be taken until four weeks after admission

Follow-up Examination From here on the results will be given for the 203 patients who showed up for follow-up examination

Limitation of Active Toe Motion Seven cases were excluded in whom the limitation was due to other causes, such as old tuberculosis, poliomyelitis or to concomitant injuries of the foot Of the remaining 196 patients, 76 1% had free motion of the toes, 10 2% had slight limitation, 3 1% had moderate limitation of flexion extension, 1 5% had severe limitation, 1 0% had stiffened toes 8 2% had claw toes Necrosis of the great toe due to disturbed circulation occurred in one case

Limitation of Active Motion of the Subtalar Joint 61 patients (31 1%) had unrestricted motion, 41 patients (20 9%) had a 33% limitation of motion Motion was limited up to 50% in 35 patients (17 85%) Motion was limited by 75% in 18 patients (9 2%) 30 patients (15 30%) had shaky movements

transfixion 85 3 days *Thus hospitalization in the conservatively* treated cases was 68 43 days while with primary osteosynthesis hospitalization lasted 106 1 days, and with medullary nailing hospitalization lasted 139 1 days Hospitalization averaged 55 3 days in uncomplicated wound healing and 140 95 days when there were wound disturbances Hospitalization was 75 2 days for patients insured against industrial accidents and 63 8 days for those not covered by insurance

The *average period of treatment* (with exception of cases of medullary nailing) lasted 234 days, 249 7 days in cases treated by extension and plaster, 173 2 days in cases treated by plaster alone and 234 1 days in cases treated by transfixion alone

The average period of treatment was *228 9 days in cases with conservative* treatment, 302 7 days in cases treated by primary osteosynthesis, 374 days in cases treated by medullary nailing The total period of treatment (as in-patient and out-patient) was 213 65 days where wound healing was without events and 328 1 days where there were wound complications The total period of treatment lasted 241 3 days in industrial accident cases and 222 1 days in non-insured accident cases

Non-union developed in 3 cases (0 7%), two in 394 cases without medullary nailing (0 8%), and one in 42 cases treated with medullary nailing (2 3%)

In 1953 I reported four cases of non-union A follow-up examination at a later date, however, showed that one of these four cases had consolidated

Consolidation Period Fractures of the tibia treated by medullary nailing were not taken into consideration since the time of consolidation cannot be determined in this type of treatment

The average period of time necessary for consolidation was 128 3 days, viz,
87 2 days in cases treated by plaster alone,
133 2 days in cases treated by traction and plaster,
124 4 days in cases treated by transfixion,
194 3 days in cases treated by primary osteosynthesis
(of these cases 376 1 days with longitudinal wire sutures,
184 0 days with tight circular wire sutures,
138 65 days with loose wire sutures,
150 0 days with crossed Steinmann pins)

Period of consolidation in relation to wound healing
117 3 days, when wounds healing was uncomplicated
115 15 days, when there were mild complications
205 05 days, when there were severe complications

The average period necessary for consolidation was 121 days in cases treated by conservative methods and 194 3 days in cases with immediate operation

Period of Consolidation and Size of Primary Wound The period necessary for consolidation definitely depends on the size of the primary wound Fractures with only a punctured wound consolidated within 97 3 days, those with large wounds needed *116 2 days for consolidation and those with extensive* wounds 218 days

Gait Of the 203 patients 188 (92 6%) had a normal gait, 5 patients (2 5%) walked with a limp, 2 patients (1 0%) limped severely, 5 patients (2 5%) walked with a limp and used a cane, one patient (0 5%) had an orthopedic splint, two patients (1 0%) had orthopedic shoes

Of those patients only 24 (6 9%) said that they could not walk longer than one hour Most of these were insured industrial accidents

Scars According to the findings of the follow-up examinations or the findings at the end of the treatment in 394 patients, 37 (94 2%) showed a smooth, painless scar, 11 patients (2 8%) had a scar which was tender on pressure, 9 patients (2 3%) had an unimportant scar hernia

Scar ulcers were not observed

Draining sinuses had existed in 3 patients (0 8%) Two sinuses were still observed at the follow-up (six and two years after the accident) One sinus had existed at the end of the treatment, but this patient did not show up for the follow-up examination

Paralysis of the Peroneal Nerve Peroneal nerve paralysis was observed in eight patients There were three primary cases and five cases which developed during treatment Three cases remained permanent

Change of Occupation Of the 203 patients 58 (28 6%) performed hard labor Only 19 patients (9 35%) had to change their occupation on account of the fracture of the lower leg

Disability Pensions Of the 377 cases of insured industrial accidents 93 patients (27 8%) draw a permanent pension Of the latter, 25 (26 7%) were older than 50 years at the time of accident The youngest was 20 at the time of accident, the oldest 68 Permanent pensions were awarded on account of concomitant injuries in 20 cases (5 95%)

Reisinger studied the 348 cases of open fractures of the lower leg which were reported to the Agricultural Accident Insurance Association of Lower Austria *in the ten years from 1939 to 1948 Of these cases 26 were treated* in the Vienna Accident Hospital, 332 in other hospitals Of the 16 patients treated in Accident Hospital 2 (12%) draw a permanent pension, of the 332 other patients 177 (50 8%)

98 CLOSED SUPRAMALLEOLAR FRACTURES OF THE TIBIA AND FIBULA

Origin Supramalleolar tibio fibular fractures usually result from indirect violence by a fall from a height of more than 1 M (figs 2513—2517, 2519) and much less frequently from the direct impact of a heavy object on the region above the ankle joint, with the foot fixed, or from a gunshot (fig 2518) These fractures are most frequently sustained by patients over 40 They are seldom encountered by young people (fig 2516)

Types of Fracture Bending fractures in which bending wedges are broken out are the rule The fracture shown in figure 2513 resembles a short torsion fracture as the bending wedge has not been broken off as in figures 2514—2517

The subtalar joint was stiffened in 11 cases (5 6%) One case (0 5%) showed ankylosis

Limitation of Active Motion in the Talocrural Joint 60 patients (30 6%) had unrestricted motion In 115 (58 7%) cases motion was slightly limited (up to 5° for extension and flexion), 18 patients (9 2%) had moderate limitation, 3 patients (1 5%) had severe limitation, 1 patient (0 5%) had ankylosis

Motion in the knee joint was normal in 163 cases (83 2%) Extension was limited by 10° in one patient (0 5%), 10 patients (5 1%) had flexion limited by 5° Flexion was limited by 10° in 11 patients (5 6%), by 15° in 7 patients (3 6%), 4 patients (2 0%) had slight limitation of extension and flexion (less than 5°) Only one patient showed extension limited by 15°, and the flexion limited by 10° in one patient (0 5%), 10 patients (5 1%) had flexion limited in plaster for 186 days Generally, the mobility of the knee joint is not affected by long immobilization

Arthrosis At the follow-up examination 64 (31 5%) of the 203 patients showed arthrotic changes of the talocrural and subtalar joints Slight arthrotic changes were encountered in 43 cases (21 2%), moderate changes in 18 cases (8 9%), severe changes in 2 cases (1 0%) Ankylosis occurred in one case (0 5%) Slight arthrosis of the knee was found in one case, moderate arthrosis in two Thus, knee joint was affected in 1 6% of the patients Arthrotic changes after open fractures of the shafts of tibia and fibula depended largely on the degree of angulation and on the age of the patient at the time of trauma, such arthrotic changes become worse with age

Relation between Arthrosis and Blood Circulation Sphygmo oscillometric measurements for the blood pressure were taken in all patients at the follow up examination By means of the sphygmo-oscillometer we can determine syn chronism of the pulses as well as fluctuations of the colume of the large and medium arteries, all of which give us a good picture of the efficiency of arterial blood supply There is a definite relation between circulation and arthrosis In patients without arthrosis the oscillometric measurements were found normal in 88 4% and lowered in only 11 6% In patients with medium and severe arthrosis these measurements were normal in 60% and lowered in 40%

Muscle Atrophy Of the 203 patients 104 (51 2%) showed no muscle atrophy in 35 patients (17 2%) the measurements of the circumference of the calf had decreased by 1 to 2 cm Muscle atrophy of up to 2 5 cm were measured in 11 patients (5 4%), up to 3 cm in 11 patients (5 4%) as well

33 patients (16 25%) with normal measurements of the circumference of the calf had swellings above the ankles, 9 patients (4 45%) had diffuse swellings

Varicose Veins Varicose veins developed after the accident in 28 patients (13 8%)

Eight patients (3 9%) had varicose veins on the uninjured leg but not on the injured leg Cyanotic discoloration of the foot on the injured side was observed in three patients (1 5%)



2515 July 17 1940 — 2515 a January 27 1955

Fig 2515 —Supramalleolar bending fracture of left tibia and fibula with lateral bending wedge broken off the tibia Valgus 20° Antecurvature 5° Sustained by a 39 year old seamstress who fell down stairs Manipulative reduction and long leg cast which was split immediately Nine days later a long leg walking cast was applied for eight weeks

Fig 2515 a —Same case 14½ years later Bony union in perfect position The fracture lines no longer visible No arthrosis Free active motion of all joints Asymptomatic Normal gait



2516 January 10 1949 — 2516 a March 26 1955

Fig 2516 —Supramalleolar bending fracture of left tibia and fibula with anterior bending wedges broken off in the metaphyseal region The distal fragment of the tibia is displaced anteriorly by a third of the width of the tibial shaft Valgus 15° recurvation 25° Sustained by a 17 year old carpenter s apprentice who fell 3 M from a ladder Manipulative reduction long leg cast which was split immediately Two weeks later long leg walking cast for an additional eight weeks

Fig 2516 a —Same case six years later Bony union in good position No arthrosis Free motion of toes and subtalar joint talocrural joint 85° to 120° as against 80° to 130° on the right side Knee and hip motion free No pain Normal gait

Concomitant Injuries Vessel or nerve injuries are rare in closed fractures

Diagnosis is simple since angulation is the rule Rotation, in addition, is usually present in open fractures Abnormal mobility and crepitation is observed only in fractures with severe displacement

Complications Following Supramalleolar Fractures of the Tibia and Fibula The same complications may occur as after fractures of the shafts of tibia and fibula (see p 1698) and they can be avoided in the same way (see p 1699)



2513 September 26 1949 2513 a March 23 1955

Fig 2513 —*Supramalleolar bending fracture of the right tibia and fibula* The bending wedge of the fibula is clearly discernible The fracture of the tibia resembles a short torsion fracture Valgus of 15° Sustained by a 56 year old coachman who fell from a moving coach Manual reduction and long leg cast which was immediately split throughout its full length Three weeks later long leg walking cast for another seven weeks

Fig 2513 a —Same case 5½ years later Bony union in good position Marginal exostosis at the anterior lower end of the tibia Toes freely mobile motion of subtalar joint limited by 25/ range of motion of talocrural joint 80° to 105° as against 75° to 115° on the left side Normal gait No significant pain Resumed his former occupation



2514 October 29 1953 2514 a August 3 1955

Fig 2514 —Supramalleolar bending fracture of the right tibia and fibula with multiple anterior bending wedges broken off the tibia The distal tibial fragment is displaced anteriorly by the full width of its shaft and laterally by half its width Recurvation (posterior bowing) 40° Sustained by a 54 year old mechanic who fell from his motorcycle Reduction in the screw traction apparatus long leg cast which was split immediately Four weeks later a long leg walking cast was applied for further six weeks

Fig 2514 a —Same case two years later Bony union with good alignment No arthrosis Free motion of toes subtalar joint limited by 25/ talocrural joint 75° to 120° as against 70° to 125° on left side Normal gait No significant pain Resumed his previous occupation

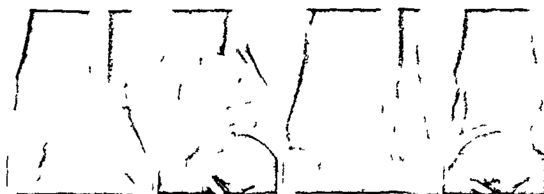
Displacements depend on the force and direction of the violence Most frequent are valgus angulations combined either with recurvation (posterior bowing) as in figures 2514, 2516, or with antecurvature (anterior bowing) as in figures 2515, 2517, depending on whether the fracturing violence strikes the lower leg from anterolaterally or posterolaterally Slight violence causes only angulation (fig 2515), severe violence also lateral displacement of up to the full width of the tibial shaft (figs 2514, 2517)



2515, July 17 1940 — 2515 a January 27, 1955

Fig 2515 — Supramalleolar bending fracture of left tibia and fibula with lateral bending wedge broken off the tibia Valgus 20° Anticurvature 5° Sustained by a 39 year old seamstress who fell down stairs Manipulative reduction and long leg cast which was split immediately Nine days later a long leg walking cast was applied for eight weeks

Fig 2515 a — Same case 14½ years later Bony union in perfect position The fracture lines no longer visible No arthrosis Free active motion of all joints Asymptomatic Normal gait



2516 January 10 1949 — 2516 a March 26 1955

Fig 2516 — Supramalleolar bending fracture of left tibia and fibula with anterior bending wedges broken off in the metaphyseal region The distal fragment of the tibia is displaced anteriorly by a third of the width of the tibial shaft Valgus 15° recurvation 25° Sustained by a 17 year old carpenter's apprentice who fell 3 M from a ladder Manipulative reduction long leg cast which was split immediately Two weeks later long leg walking cast for an additional eight weeks

Fig 2516 a — Same case six years later Bony union in good position No arthrosis Free motion of toes and subtalar joint talocrural joint 85° to 120° as against 80° to 130° on the right side Knee and hip motion free No pain Normal gait

Concomitant Injuries Vessel or nerve injuries are rare in closed fractures

Diagnosis is simple since angulation is the rule Rotation, in addition, is usually present in open fractures Abnormal mobility and crepitation is observed only in fractures with severe displacement

Complications Following Supramalleolar Fractures of the Tibia and Fibula The same complications may occur as after fractures of the shafts of tibia and fibula (see p 1698) and they can be avoided in the same way (see p 1699)



2517 June 18 1955 2517 a October 17 1955

FIG 2517 —*Open* supramalleolar bending fracture of left tibia and fibula with lateral bending wedges The fracture lines reach into the ankle joint A big posterior and an anterolateral wedge have been broken off of the distal fragment The distal fragments are displaced lateroposteriorly by two thirds of the tibial shaft s width Valgus 30° antecurvature 30° On the medial side of the lower leg is a transverse wound (8×3 cm) with badly lacerated edges Sustained by a 65 year old engineer who fell 2 M from a ladder Insertion of a calcaneus pin Thorough wound excision under local anesthesia cleaning of the bone with a rongeur apposition of the fracture ends As strong tension of the skin was present on attempting to close the skin, 2 cm of the proximal fracture end was removed The proximal fragment was then driven into the cancellous bone of the distal fragment Insertion of a drain skin suture long leg cast (which was split immediately) for 3 months Continuous traction of 3 Kg Superficial skin necrosis 3×2 cm Three months later long leg walking cast for another month

FIG 2517 a – Same case after four months on removal of the cast Fracture has united with a shortening of 2 cm Good alignment in the anteroposterior view the lateral view shows 10° recurvation

Treatment of Closed Supramalleolar Fractures of the Tibia and Fibula

The production of an adequate shortening is the most important task in the treatment of fractures since, due to rupture of vessels and subsequent impairment of circulation, every fracture is followed by devitalization and absorption of the fracture stumps, of from 0 5 to 3 mm An opportunity must, therefore, be given the fracture stumps to approach each other The aim of treatment should be to produce a shortening of from 1 to 5 mm after every fracture, and under no circumstances, a lengthening This statement may cause some surprise, because up to now the aim has always been to eliminate any shortening The amount of shortening to strive for should, as a rule, not exceed 5 mm

Lengthening of a bone by separation of the fracture ends (Dislocatio ad longitudinem cum elongatione aut distractione) is the most dangerous of all displacements since all those severe complications may follow which have been described in Vol I/pages 25—27 (fig 2518)

Treatment of Fracture with Angulation and Slight or No Lateral Displacement in the Cast (figs 2513 2515 2516) The lower leg is bent straight under local anesthesia If the roentgenograms show correction of angulation and lateral displacement in both projections, a long leg cast is applied as described



2518 August 11 1942 — 2518 a January 11 1944

Fig 2518 —Infected supramalleolar comminuted gunshot fracture 5 weeks after the injury Traction of 6 kg no cast The main fragments are separated by 2 cm diastasis of the talocrural joint Severe demineralization In this position of distraction a transfixion cast with two incorporated wires (figs 2447—2457) was applied for further six weeks A lower leg cast followed for 14 months Sustained by a 30 year old soldier through an explosive bullet Treated at another hospital

Fig 2518 a —Same case 14 months after the injury and 1 month after excision of a piece of the fibula The tibial fragments have approached each other Draining pseudarthrosis of both bones whereas the bones in fig 2517 a united after 4 months



2519, May 21 1937 — 2519 a July 8 1938

Fig 2519 —Nine weeks old supramalleolar fracture of the tibia and fibula with 35° recurvation Sustained by a 50 year old officer who fell from his motorcycle on March 18 1937 Was treated at another hospital with a short leg cast for 6 weeks Secondary bending on account of immobilization for too short a time Nine weeks after the injury correction with the Phelps Gocht osteoclast followed by a full leg cast for 8 weeks

Fig 2519 a —Same case after 14 months Bony union in good alignment

on pages 1724, 1725 The cast is immediately split and is replaced in 2 weeks by a long leg walking cast for a further 6 weeks

Treatment of Fractures with Slight or No Displacement by Traction and Subsequent Long Leg Walking Cast (figs 2513, 2515, 2516) A calcaneus pin

is driven in under local anesthesia, the lower leg is bent straight and treated by continuous traction weighted with 1 to 2 Kg as described on pages 1704—1719 Two weeks later a long leg walking cast *is applied for further 6 to 8* weeks, as described on pages 1724—1731

Further treatment, after removal of the long leg walking cast, is carried out by Unna's paste boot, as described on pages 1733, 1734

Treatment of Fractures with Severe Lateral Displacement (fig 2514) These fractures cannot, as a rule, be reduced manually A calcaneus pin should, therefore, be driven through the calcaneus, and the fracture should be reduced under local anesthesia in the screw traction apparatus (see p 1710) Continuous traction should be weighted with 1 to 2 Kg for 3 weeks (see pp 1704—1709) A long leg walking cast is applied for an additional seven weeks (see pp 1724—1731) and then an Unna's paste boot (see pp 1733, 1734)

99 OPEN SUPRAMALLEOLAR FRACTURES OF THE TIBIA AND FIBULA

Origin Open supramalleolar fractures of the tibia and fibula are caused by the same mechanism as closed fractures, but by a greater traumatizing force These fractures are often displaced by the full width of the tibial shaft (fig 2517, M N /fig 894) Laceration of the skin is usually transverse or oblique to the long axis of the limb The length of the laceration may extend as far as half the circumference of the lower leg

Diagnosis Diagnosis is usually simple as the proximal fragment protrudes from the skin similar to figure 2486

Treatment Treatment is performed as in open fractures of the shafts of tibia and fibula Next to preservation of life and limb, prevention of infection is of greatest importance The most efficient means is *thorough wound excision* within the first 8 to 10 hours (see p 1771) followed by *suture of the skin without tension* (see p 1773) since closure of skin is the main problem in all open fractures and joint injuries Antibiotics are a valuable help against infection

Shortening of the Tibia in Loss of Skin If closure of the damaged skin without tension is impossible after wound excision and reduction of the fragments in the open wound, the proximal fragment should be shortened by 1 to 2 cm and the tibial shaft should be driven into the cancellous bone of the metaphyseal region (fig 2517 a) Bone excision must not exceed 2 cm because in that case the skin cannot be closed either

Immobilization After insertion of a drain and completion of the skin suture a long leg cast is applied with the patient on the screw traction apparatus or offhand as described on pages 1774—1778 The cast is immediately split throughout its full length and fenestrated

Further treatment is carried out as described on pages 1779—1783

100 INFECTED SUPRAMALLEOLAR FRACTURES OF THE TIBIA AND FIBULA

These fractures are treated in the same way as infected fractures of the shafts of the tibia and fibula (see pp 1792—1800) It must be made a point

to refrain from reduction in the screw traction apparatus No attempt should be made to correct a lateral displacement as severe progressive infection may flare up (see Vol I/p 160, p 1793)

101 OLD AND MALUNITED SUPRAMALLEOLAR FRACTURES

Supramalleolar fractures united with angulation (fig 2519) may be bent straight within the first 2 to 3 months either over a padded wooden wedge or by means of a Phelps Gocht osteoclast (fig 2746, 2519 a)

If the fracture is of long-standing, a wedge osteotomy (fig 2576, 2577) or still better a V-shaped osteotomy (fig 2580) should be performed

Questions We Should Ask Ourselves in Order to Avoid Failures in the Treatment of Supramalleolar Fractures of the Tibia and Fibula

The questions are the same as in the treatment of closed, open, and infected fractures of the shafts of tibia and fibula (see pp 1715, 1718, 1735, 1788—1792)

1 Have I only bent straight and not reduced under screw traction fractures without appreciable lateral displacement?
2 Have I immediately reduced fractures with severe lateral displacement in the screw traction apparatus and refrained from attempts to correct the position by continuous traction with heavy weights?
3 Have I shortened the proximal tibial fragment in open fractures with loss of skin, and driven it into the distal fragment to make closure of the skin possible without tension?
4 Have I, in open and infected fractures, refrained from attempts of secondary correction of lateral displacement?

102 TERMINOLOGY OF ANGULATION AND ROTATION IN THE NORMAL, MORBID, AND INJURED LEG AND FOOT

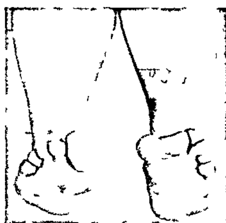
The mechanism of motion in the talocrural, subtalar, and talonavicular joints as well as in the tarso-metatarsal joints is rather complicated Various terms are used to determine the position of the foot as a whole, or either the anterior or the posterior part of the foot

Angulation of the lower limb, from the femoral neck down to the heel, when occurring in the frontal plane is called either varus, if the angle is open at the medial side, or valgus if the angle is open on the lateral side In fractures of the femoral neck, varus fractures are called adduction fractures, and valgus fractures are generally called abduction fractures In the knee region we usually speak of either varus position (genu varum — bow leg), or valgus position (genu valgum — knock-knee), and not of adduction or abduction At the talocrural joint (ankle joint) and the subtalar joint a varus position is also called supination, and a valgus position is called pronation Terms as adduction fractures and abduction fractures are also used in this region

Angulation at the tarsus is usually called adduction and abduction Angulation at the big toe is, as a rule, called hallux valgus or hallux varus At the small toe the term digitus quintus varus or adductus is used

In the normal foot active circular movements can be performed in the talocrural, subtalar, and talonavicular joints In these movements supination is combined with adduction, and pronation is combined with abduction

If the foot is fixed, and either the lower leg is actively rotated outwards in the knee joint (the knee being flexed to a right angle), or the limb is actively rotated outwards in the hip joint (with the knee extended), the talus, which is held fast within the malleolar fork, follows the motion of the lower



2519 b April 2 1930



2519 c December 30 1927

FIG 2519 b—Severe flat foot on the left side with hallux valgus When not bearing weight the heel is straight while the fore foot is supinated in relation to the heel Both longitudinal and transverse arches have disappeared The right foot with the normal torsion of the fore foot shows good longitudinal and transverse arches The left foot is abducted at the mid tarsal joint adducted at the tarsometatarsal joint while the great toe shows compensatory abduction

FIG 2519 c—Claw foot on the left side The heel is slightly supinated and in relation to the heel the fore foot is pronated This causes an exaggeration of the longitudinal arch In addition the fore foot is markedly adducted

leg, i e, rotates with its anterior part (caput tali) outwards on the underlying calcaneus The caput tali is lifted at the same time This motion also causes supination of the calcaneus and adduction of the fore foot (metatarsal region) The medial part of the fore foot is not lifted with the caput tali but rotates inwards round its long axis Thus, the medial part of the fore foot becomes pronated The first metatarsal becomes plantar-flexed The lateral roentgenogram shows crossing of the first and fifth metatarsals The inner (longitudinal) arch of the foot rises

If the leg is rotated inwards the foot being fixed on the ground the talus rotates inwards too, and the caput tali sinks Valgus i e pronation of the calcaneus is the result, as well abduction and relative supination of the fore foot The inner arch of the foot flattens (see p 1624)

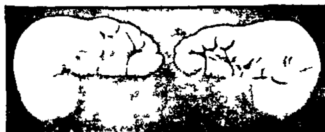
A sufficiently strong force, e g, a forceful turning of the body toward the fixed foot will rupture ligaments and fracture bones The foot will be

rotated, relative to the body, either outwards or inwards, i e, external or internal rotation of the foot

Rotation of the foot round its own long axis is called pronation or supination Rotation of the foot round the long axis of the lower leg, as has been mentioned above, is called external and internal rotation

103 THE POSITION OF THE FORE FOOT IN FLAT-FOOT, CLUB-FOOT, AND CLAW-FOOT

The commonest result of fractures of the malleoli and tarsal bones is traumatic flat-foot It is constantly advised that the fore foot should be held in supination to prevent this But the following will show that this position will produce instead of prevent flat-foot



2519d February 4 1921



2519 e December 8 1921

FIG 2519 d—Extreme congenital club foot on both sides Corns on the outer edge of the foot from walking The heel is supinated the fore foot is extremely adducted and markedly pronated

FIG 2519 e—Same case after ten months Manipulation on three occasions at two month intervals The marked supination has completely disappeared on the right and almost on the left Adduction has disappeared After manipulation an unpadded plaster cast was applied with which the 17 year old boy could walk two days after each operation

Flat-foot according to the definition hitherto accepted, is a foot which is flexed, pronated, abducted, and turned outwards, i e, it is plantar-flexed at the talocrural joint (ankle joint), pronated at the subtalar joint (talo-calcaneal joint), and abducted and dorsiflexed at the midtarsal joint

Club-foot is a foot which is flexed, supinated, adducted, and turned inwards that is, at the ankle joint it is plantar-flexed, at the subtalar joint it is supinated, and at the mid tarsal joint and tarso-metatarsal joint it is adducted and strongly plantar-flexed

Claw-foot is described as a hollow foot, that is, the arches are exaggerated

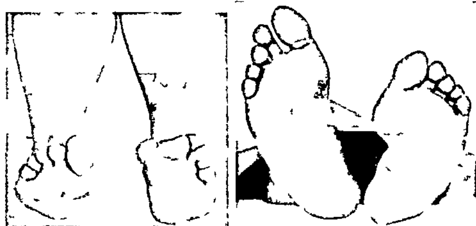
Flat-foot has been usually considered the mirror image of club-foot, and the treatment produced a flat-foot out of a club-foot and a club foot out of a flat foot

If the definition of flat foot were correct anyone with a flat-foot (pes valgus or plano valgus) must walk on the inner edge of the foot (fig 2519 f,

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2519 b April 2 1930 2519 c December 30 1927

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If the leg is rotated inwards the foot being fixed on the ground the talus rotates inwards too, and the caput tali sinks Valgus, i e, pronation of the calcaneus is the result, as well abduction and relative supination of the fore foot The inner arch of the foot flattens (see p 1624)

A sufficiently strong force, e g, a forceful turning of the body toward the fixed foot, will rupture ligaments and fracture bones *The foot will be*

foot If this were not the case a patient with flat foot would always walk on the inner side of the foot This detorsion or supination of the fore foot occurs in the mid tarsal, and tarso metatarsal joints, so that every bone in the tarsus has its position slightly altered, the cuboid being affected least of all The detorsion or supination is most marked at the inner border of the foot and decreases towards the outer, so that the fifth metatarsal bone forms the axis



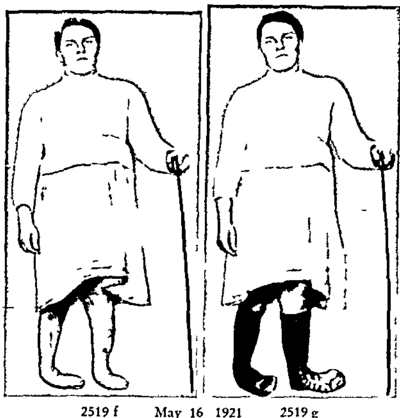
2519 h November 18 1921 2519 i

FIG 2519 h i—Same after six months Both feet in normal position The ulcer over the tibia has healed Closed manipulation of both feet followed by walking casts for five months It is interesting to note what a good influence the operation has had on her bearing and facial expression

round which the rotation of the fore foot in the direction of supination takes place The flattening of the inner arch is not the result of dropping, but of this detorsion or supination of the fore foot on the talus and calcaneus The transverse arch also disappears (fig 2519 b) The final flattening of the inner and longitudinal arches is secondary Then by well-marked stages the bones, joints and soft parts undergo changes, on one side the ligaments, tendons, and muscles are shortened, and on the other they are lengthened The disappearance of the longitudinal arch by detorsion or supination of the fore foot can easily be demonstrated in every skeleton and in every person in whom there is no fixed contracture of the root of the foot

The definition of flat-foot should therefore be pes flexus, pronatus, abductus reflexus, *supinatus* — i e, in a flat foot there is plantarflexion at the upper (talocrural) ankle joint, pronation at the lower (subtalar) ankle

g left) as a patient with club-foot walks on the outer edge of the foot (fig 2519 d, f, g right) In reality the patient with flat-foot walks with the whole sole on the ground This is only possible if the fore foot is rotated through its long axis in the direction of supination on the calcaneus and talus By the fore foot is meant all that part of the foot which lies in front of the mid-tarsal joint



2519 f May 16 1921 2519 g

Fig 2519 f —Foot deformities following infantile paralysis In the right foot the heel and the forefoot are supinated in addition to which the forefoot is adducted On the left the heel and the fore foot are pronated and the fore foot is also abducted This is a true pes pronatus which is seen in flaccid or even most often in spastic paralysis Congestive ulcer on left leg

Fig 2519 g —The patient walked on the outer edge of the right and on the inner edge of the left foot the soles of both feet being vertical

A peculiarity of the human foot is the torsion in the direction of pronation of the calcaneus (position of valgus) In anthropoid apes the foot is supinated, to give a grip and the pronation of the calcaneus is absent This pronation of the calcaneus is of the utmost importance to human beings for standing and walking because it permits the passage of the deep tendons of the foot and flexors of the toes, and may produce the greatest trouble if the calcaneus is pronated a few degrees too much when all the severe changes follow which we call flat-foot

Flat-foot has always been spoken of as though it consisted of a dropping of the longitudinal arches First the outer arch drops and then the inner In reality, however, the conditions are that at the same time there occurs hypertorsion (pronation) of the heel and detorsion (supination) of the fore

bone usually remains in abduction because it is held by the strong metatarso cuboid ligament This is the origin of the splay foot Adduction at the tarso metatarsal joint is favored by various circumstances As the result of detorsion (supination) of the fore foot the inner margin of the foot is lengthened and this causes the abductor hallucis to be overstretched at the same time, as the result of the detorsion, it slips from the inner side to the under aspect of the margin of the foot The head of the first metatarsal thus loses a great part of its support The peroneus longus, inserted into the base of the first metatarsal, cannot offer resistance to medial deviation of the first metatarsal because of its unfavorable lever relationship Furthermore, the distal joint surface of the medial cuneiform bone is directed from in front and on the outer side, backwards and inwards The result is that the transverse tarsal arch drops, or if the first metatarsal is strongly adducted, hallux valgus is produced i e, compensatory abduction of the great toe (fig 2519 b)

Club-foot includes in slight cases only a varus position or supination of the heel, the fore foot remaining fully in contact with the ground There is then pes flexus, supinatus adductus, pronatus — that is, the foot is plantar-flexed at the ankle joint, supinated at the subtalar joint, adducted at the mid tarsal and tarso metatarsal joints (fig 2919 d) and the fore foot is pronated

Claw-foot is generally regarded merely as a foot with a hollow that is an exaggerated arch It is a pes supinatus (varus), inflexus, pronatus — i e, the heel is usually in slight supination, or varus position, the fore foot is plantar-flexed at the tarsal joints, and the greatest deformity consists in the marked pronation of the fore foot, which for the most part takes place in the tarso-metatarsal and intertarsal joints, and only to a slight extent in the talo-navicular joint The great hollow of the claw-foot is produced chiefly by pronation — that is, hypertorsion of the fore foot — rather than by inflexion (fig 2519 c)

The claw-foot is the true opposite of the flat-foot It usually originates from complete or partial paralysis of the tibialis anterior If this muscle alone is weak there are two possibilities Weight-bearing is either started soon, then a paralytic flat-foot will result, development of which is promoted if the tibialis posterior is also weak, or the foot is not used, then a claw foot will result If no weight is borne, and if the tibialis anterior is paralyzed, the fore foot will become plantar-flexed at the tarsal and midtarsal joints (inflexion) The non-paralyzed peroneus longus pulls the fore foot plantarwards and can at the same time act as a pronator of the fore foot, as it takes its course round the outer edge of the foot and has its attachment at the base of the first metatarsal The peroneus longus also supinates the heel The claw position of the toes in the claw-foot is often compared with the claw-hand in ulnar paralysis There is, however, no relation, as the claw-toes are due to mechanical forces rather than to nervous causes As the dorsum of the foot is very high, the extensor of the toes must take a longer course, thus becoming, relatively, too short The toes, therefore, become extended in the basal (metatarso phalangeal) joints The flexors of the toes however, have a shorter way in the case of an exaggerated arch, and do not hinder hyperextension of the basal joints The long extensors of the toes are also dorsiflexors of the ankle joint As they

joint, abduction and dorsiflexion at the mid-tarsal joint, and, what is most important, the entire fore foot is supinated and not pronated Flat-foot does not consist in pronation of the whole foot but in pronation of the calcaneus while the entire remainder of the foot is in supination in relation to the calcaneus This can be seen in the majority of flat-feet not bearing weight, by looking at the soles of the feet (fig 2519 b) If there is no actual contracture of the calcaneus in a valgus position, this bone will become straight *when no weight is upon it*, that is, it will be in normal position of torsion, while at the same time the fore foot rotates in pronation

When weight is borne on the leg adduction of the talus causes the leg to rotate inwards, because the talus is fixed in the socket of the ankle and takes the leg with it (see p 1507)

This new concept of flat-foot as a supination contracture of the fore foot refutes the idea of Albert, that every genu valgum had a compensatory pes varus, and also the opinion put forward by an English orthopedic surgeon that flat-foot always exists with genu valgum Actually the conditions are such that with genu valgum the calcaneus may be in pronation, sometimes is normal and sometimes in slight varus, i e supination, the fore foot, however, must always be in supination, which is proportional in degree to the degree of valgus at the knee joint Supination of the fore foot on the heel signifies flattening of the inner arch, and flattened inner arch is evidence of a flat-foot The opinion that genu valgum is associated with flat-foot is correct, and moreover Albert, in saying that genu valgum is always connected with pes varus, is also correct in the sense that the foot is supinated

The important factor in flat-foot is a torsion, that is, pronation of the heel, following a weakness of the supinators (tibialis posterior, flexor hallucis longus, and flexor digitorum longus), and this involves detorsion (supination) of the fore foot In this detorsion the head of the first metatarsal is raised, which flattens the inner arch As a result of this flattening of the arch, the bones which comprise it — the cuneiform and the navicular — are depressed towards the ground the head of the talus necessarily dropping at the same time Flexion therefore must occur at the ankle with movement in the opposite direction at the mid-tarsal joints Abduction is produced in that detorsion of the fore foot causes relaxation of the tibialis anterior, which at the same time is a dorsiflexor supinator, and adductor of the fore foot, while the peroneus longus, which is a plantar-flexor, pronator, and abductor of the fore foot, is stretched In standing the supinated fore foot can neither be pronated nor plantar-flexed, so that the peroneus longus can only act as an abductor of the fore foot The relaxation of the tibialis anterior caused by the supination of the fore foot affords no opposition When marked abduction is reached it is again tensed Therefore in the contracted flat-foot of young people the tibialis anterior stands out just as strongly as the peroneus longus

A simple abduction *contracture of the fore foot is not common* With abduction at the mid tarsal joint there is usually a corresponding adduction at the tarso-metatarsal joint, this adduction being most marked at the first metatarsal bone, becoming less on the outer side The fifth metatarsal

is fixed for a long time in an exaggerated position of pronation, a pronation contracture of the fore foot will occur, and then when the patient walks he tries to tread with the whole of the fore foot, the heel being again brought into a varus position This is then considered as a case of intractable club foot

Contractures of the tarsus consist for the most part in altered positions of the tarso metatarsal and intertarsal joints, particularly of the first tarso-metatarsal joint Movements of this joint are small, but they produce great changes, because a slight movement at this joint causes considerable movement at the long lever arm of the metatarsals and the toes Hitherto chiefly the changes in the joints of the talus have been taken into consideration

104 INTRA-ARTICULAR SHEARING AND COMMINUTION FRACTURES OF THE LOWER END OF THE TIBIA AND FIBULA

Origin and Types of Fractures Shearing and comminution fractures of the lower end of the lower leg usually result from indirect force by falls from a height of more than 1 M (figs 2536, 2543—2550) or by a collision in motor driven vehicles (figs 2535, 2539, 2541)

In 1955 Jahna and Trojan[1] surveyed our 442 fresh and old cases The majority of these patients were re-examined by Jahna and Trojan and were repeatedly discussed with me The fracture types were classified by Jahna and Trojan in their paper from a morphological standpoint My own classification given in this chapter is etiologic, i e, it takes into account the origin and mechanism of the injury

Direct violence, such as an impact of heavy objects, is rare The rule is comminution due to impaction in the long axis of the lower leg (figs 2521—2528) either alone, or combined with a simultaneous torsion or bending of the lower leg (figs 2529—2534), the foot being in various positions The types of fracture are manifold, depending on whether the force acted when the ankle joint was excessively plantar-flexed (fig 2521) or dorsiflexed (fig 2522), or the tarsus was supinated (fig 2527) or pronated (fig 2528), whether dorsiflexion was combined with pronation (fig 2531) or internal rotation (figs 2533 2534) and supination (figs 2529, 2530) In spite of gross distortion of the fragments (figs 2532 2549, 2550), the types of fracture can usually be recognized, especially after reduction (figs 2547—2550) In addition, the form of the fracture depends on the body weight and age of the patient, the calcium content of his bones, the height of the fall, the speed of the colliding vehicle, the character of the ground (hard, soft, plane, oblique), the position of the body and on the shape of the foot and its position at the moment of the trauma

The common malleolar fractures (figs 2610—2617, 2633—2640, 2666—2667), in contradistinction to the shearing and comminution fractures of the supramalleolar region, originate as external rotation fractures when the body is twisted away from the fixed or weight-bearing foot

[1] Jahna H and Trojan E Behandlungsergebnisse der supramalleolaren und intra artikularen Bruche am unteren Ende des Unterschenkels Hefte zur Unfallheilk, 1956

are overstretched due to the abnormal arch of the foot, the foot does not drop at the ankle joint The mechanism of the claw-position of the toes can easily be explained by the fact that the toes become extended when the foot is dorsiflexed

The above observations are of the greatest importance in the treatment and prevention of these deformities Hitherto the general advice has been that the flat-foot should be converted into a club-foot by manipulation, whether this is by open operation or by bloodless methods Either by manipulation or by a wedge-shaped resection the whole foot was placed in marked supination, adduction, and inflexion, and there fixed by plaster Many advise full supination of the fore foot, so that the sole would face its fellow as in the Buddha position By this procedure the supination contraction of the fore foot is accentuated in the highest degree What is the result? The patient once more steps with the whole sole of the foot on the ground and the heel is even more in a valgus position than before the operation In many cases the supinated position is retained in walking and the patient is left with a club-foot and has to wear splints

The rational treatment of flat-foot consists in the following manipulation The pronated heel should be brought into slight supination and at the same time the supinated fore foot should be pronated, twisting the foot round its long axis in the opposite direction to the heel The flat-foot should be converted into a claw-foot A good arch will be formed by counter rotation of the fore foot, without excessive inflexion The greater part of the abduction disappears on pronating the fore foot The correction of flat-foot is thus very simple and can nearly always be done by bloodless manipulation The foot is manipulated into a position of well-marked claw-foot, but the plaster cast is applied in a position of only slight overcorrection It is sufficient to retain the cast for twelve weeks, after which Unna s paste boot is applied for a further ten weeks, and arch-supports for a year The patient can walk two days after the manipulation The correction of flat-foot should only be undertaken in patients under thirty years of age

A claw-foot should be converted into a flat-foot The slight supination of the heel should be converted into slight pronation and the same time the pronated fore foot should be supinated In this way the greater part of the exaggerated arch will disappear, even the toes will become straightened The remaining exaggeration of the arch of the foot can easily be corrected by manipulation without resection of a wedge Transplantation of tendons is usually unnecessary

The operation for club foot is usually carried out so as to convert it into a flat-foot In reality this will not make a flat-foot but a pronated foot — that is, the outer edge of the foot will be placed higher than the inner, but as flat-foot does not consist in pronation but in a supination contracture of the fore foot, raising the outer edge of the foot will not produce flat-foot because the inner longitudinal arch still remains The correct cast for the correction of club-foot should so be placed as to keep the heel in slight pronation and the fore foot in abduction and relative supination — that is, so as to bring the heads of the first and fifth metatarsals to the same level If the fore foot

Volkmann s triangle, but as it has more than two dimensions, it should be called a wedge This fracture dislocation usually occurs in heavy women over the age of 40

Shearing Fractures in the Frontal Plane with Anterior Displacement of the Foot If a person falls on his feet while slightly bent forward or if the ground on which the person falls slopes upward, extreme flexion of the ankle joint pushes the posterior edge of the tibia away from talus so that only the anterior tibial edge remains in contact with the talus A frontal fissure results in the lower end of the tibia Should the force continue, the anterior wedge is tilted anteriorly if the base of the wedge is small (fig 2524) If its base is broad, it, together with the foot, becomes displaced forward and upward (fig 2525) In these cases the medial malleolus is, as a rule, sheared off (figs 2525, 2535) A greater force ruptures the posterior capsule and ligaments (fig 2522/II) The posterior part of the tibia subluxates backward The foot together with the anterior fragment subluxates forward and upward (figs 2522/III, 2526, 2536) If the violating force is great enough and the dorsal part of the tibia subluxates far enough, an additional small wedge is sheared off from the anterior edge of the dorsal fragment This wedge is either tilted (figs 2522/III, 2546) or displaced upward to a varying degree (figs 2526, 2536) The displacement of this small intermediate fragment indicates how far cranialward the talus and the foot were displaced at the time of the trauma When the violence has ceased the foot drops and the intermediate fragment remains in its displaced position (fig 2526) A forward fall with the ankle in extreme flexion may also cause a transverse fracture of the neck of the talus

Shearing and Impaction Fractures in the Frontal Plane Caused by Simultaneous Internal Rotation and Supination These fractures originate if the body falls forward, shearing off an anterior wedge and in addition rotates (outward) toward the fixed foot so that the foot becomes rotated inward (in relation to the body) and supinated In addition to the shearing off of the anterior wedge an internal torsion fracture of the tibia and the fibula occurs and the medial malleolus breaks off (figs 2529, 2530, 2545, 2546) Both an anterior and a posterior wedge result

Shearing Fractures in the Sagittal Plane with Medial Displacement of the Foot (Supination—Adduction Fractures or Varus Fractures) These fractures result from impaction in the long axis of the lower leg if the body either falls on the ground or hits against an obstacle (fig 2539) while the foot is in extreme supination and adduction Medial dislocation of the foot results The lateral malleolus may be avulsed transversely either at the joint level (fig 2683) or near its lower end (figs 2527, 2539) Sometimes, only the ligament ruptures and the lateral malleolus remains intact In complete dislocation the skin ruptures transversely so that the lateral ankle projects from the wound In severe dislocation of the talus a small part of the edge of the lateral tibial fragment becomes sheared off and displaced upwards (figs 2527, 2539)

Shearing Fractures in the Sagittal Plane with Lateral Displacement of the Foot (Pronation—Abduction or Valgus Fractures) These fractures occur very seldom, they result either from a fall on the pronated foot or from the impact

Shearing Fractures in the Frontal Plane with Dorsal Displacement of the Foot Partial or complete rupture of the anterior capsule and ligaments of the ankle joint will ensue if a violent force acts in the long axis of the lower leg when the foot in extreme plantarflexion The anterior margin of the lower end of the tibia becomes displaced forward and the force acts on the posterior margin of the lower end of the tibia A crack in a frontal plane results (fig 2521/I) *If the force continues, the posterior bone wedge is sheared off, and,* together with the foot, displaced dorso-cranially (i e, backward and upward)

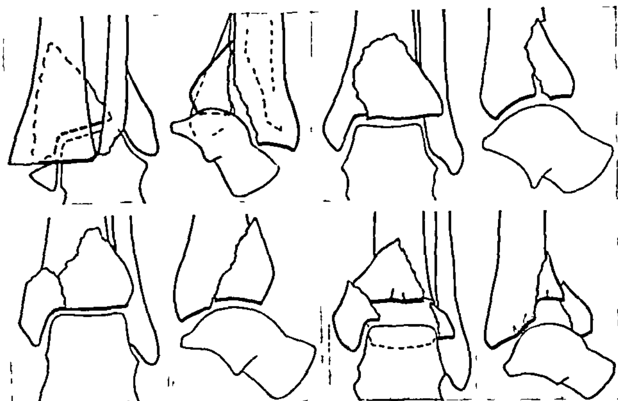


2520 May 2 1928 2520 a October 24 1955

FIG 2520—*Open* supramalleolar flexion fracture of the right tibia and fibula with avulsion of the medial malleolus and double transverse fracture of the fibula Valgus 20° antecurvature 15° Sustained by a 46 year old stoker who was hit by a heavy weight on the posterolateral side of his lower leg Treatment Accurate wound excision apposition of the fragments insertion of a drain suture of the skin and the skin alone insertion of a calcaneus pin reduction in the screw traction apparatus plaster cast which was split immediately and fenestrated over the wound traction weighted with 3 kg for 5 weeks followed by a long leg walking cast for further six weeks

FIG 2520 a—Same case 27½ years later Normal shape and normal color of the leg Free motion of toes Subtalar joint limited by 50% Ankle joint 80° to 115° as against 70° to 120° on the uninjured side The 72 year old man has no pain in his leg Normal gait

(figs 2521/II, 2523, 2537, 2538) This may happen when a person falls down stairs and gets caught with the heel on a step (figs 2521/I II, 2538) It happens even more often when a person slips and comes to sit on his heel (figs 2521/II a, 2523, 2537) In this case the lower leg is fixed and the talus moves The medial and the lateral malleolus are usually avulsed at the same time The anterior part of the tip of the medial malleolus usually remains in place (figs 2538) In the case shown in figure 2538 the displacement shows that the violence acted in a purely frontal plane If there is a valgus deformity besides the posterior displacement, as in figure 2537, it is a sign that the body also fell to the lateral side at the same time, or in the presence of varus, to the medial side That part of the bone which has been sheared off is often called



2523—2526 Sketched in October 1955

Impaction and Shearing Fractures in the Frontal Plane

FIG 2523 (top left)—Shearing off of a big posterior wedge of the tibia Upward and posterior displacement of this wedge together with the foot Sustained by slipping on the road and sitting onto the heel Compare fig 2511/II a Treated with screws (fig 2537 a)

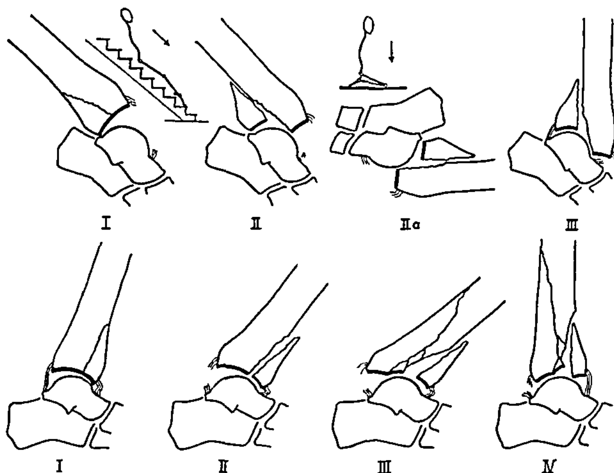
FIG 2524 (top right)—Shearing off of an anterior wedge of the tibia with upward and anterior subluxation of the foot Sustained by a 2 M fall The wedge has a comparatively small base and is tilted with its lower part forward and upward Treated with screw fixation

FIG 2525 (bottom left)—Shearing off of a big anterior wedge and the medial malleolus with upward (cranial) and forward (ventral) subluxation of the foot The wedge has been displaced parallel to its fracture plane but not tilted Sustained in a 3 M fall Treated with screw fixation (fig 2535 a)

FIG 2526 (bottom right)—Shearing off of a big anterior wedge which has been broken into several parts Shearing off of the medial malleolus and of an anterolateral wedge of the tibia The intermediate portion of the tibial articular surface is impressed the anterior wedge is displaced upward by 20 mm The foot is subluxated far upward and forward Treated with screw fixation (fig 2536 a)

pressed and an anterolateral wedge is sheared off (figs 2528, 2540) A vertical fall on the feet usually causes the fracture of one or both calcanei The lateral wedge of the talus splits the calcaneus

The result of a fall on an oblique surface can be clearly seen in figures 2547 2548 When a person stands on an oblique plane with the feet sideways, the foot standing higher is forced into valgus, and the foot standing lower is forced into a varus position With this in mind, one can see from the roentgenogram that the woman of figures 2547, 2548 hit the ground at first with her left and then with her right foot On the left side, where she hit the ground first, a pronation abduction fracture occurred with extreme valgus and complete



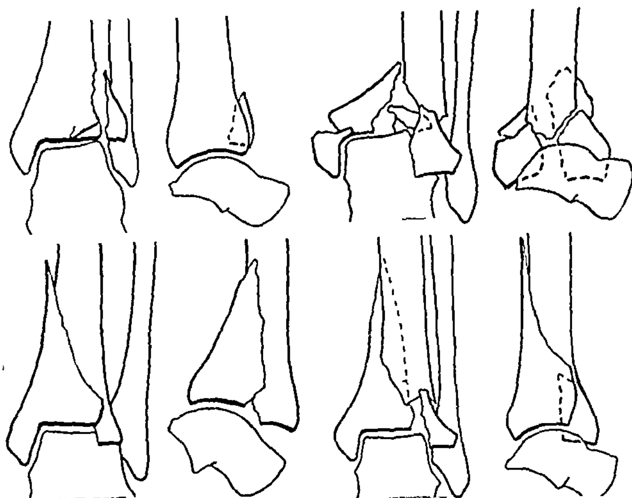
2521, 2522 Sketched in October 1955

Shearing Fractures in the Frontal Plane

FIG 2521 (top row)—*Mechanism of an impaction fracture at the distal end of the tibia with* shearing off of a big posterior wedge e g in I by a fall down stairs where the heel of the foot gets caught on a step Extreme plantarflexion of the ankle joint causes rupture of the anterior capsule and ligaments and a frontal split through the center of the lower articular surface of the tibia If the force continues the tibia subluxates distally as shown in II The same mechanism takes place if a person trips with the tip of his foot but catches himself and with the knee flexed comes to sit on his heel as in II a In the subsequent fall to the side the plantarflexion of the foot decreases The anterior tibial fragment glides forward as fa as the neck of the talus as shown in III and in fig 2537

FIG 2522 (bottom row)—Mechanism of an impac ion fracture at the distal end of the tibia with shearing off of an anterior wedge of the tibia Such a fracture results from a fall from a height of more than 1 M when at the same time the ankle joint is dorsiflexed If capsule and ligaments rupture at the posterior side of the ankle joint the force acts on the anterior edge of the distal end of the tibia A frontal split results in the anterior part of the articular surfa e as shown in I Continuation of the force creates anterior subluxation of the foot as in II and fig 2524 Sometimes a small wedge is sheared off from the posterior tibial fragment as in III and figs. 2526 2546 When the body falls to the side he foot becomes slightly plantarflexed and the fragments can approximate each other The anterior subluxation however remains as a rule as shown in IV and figs 2546 2547

of a heavy object on the supramalleolar region A bending fracture of the lateral malleolus with a lateral bending wedge results, as well as a transverse avulsion of the medial malleolus at joint level In the pronation fracture caused by a fall, the lateral part of the lower tibial articular surface is im



2531—2534 Sketched in October 1955

Impaction Fractures with an Anterolateral Wedge Broken Off of the Tibia

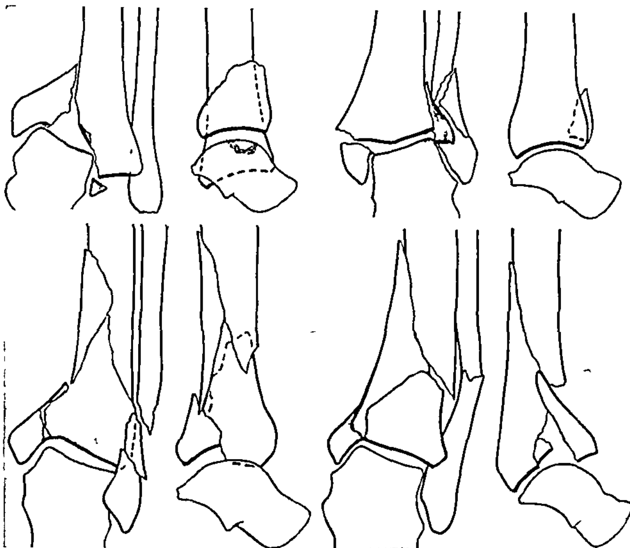
FIG 2531 (left top)—Anterolateral wedge broken off from the tibia, impression of the antero lateral part of the articular surface Caused by impaction in the long axis and dorsiflexion with the fibula remaining intact
Treated with screw fixation (fig 2541)

FIG 2532 (top right)—Comminution fracture of the tibia with an anterolateral wedge of the tibia being sheared off accompanied by a fracture of the articular surface of the tibia and fracture of the medial malleolus Sustained in a fall of 3 M The fibula remains intact Central subluxation Treated by reduction with screw traction followed by continuous traction (fig 2549)

FIG 2533 (left bottom)—Impaction and torsion fracture at the lower end of the tibia with central dislocation of the foot while an anterolateral part of the tibia has remained in place Treated by reduction with screw traction followed by continuous traction (fig 2542)

FIG 2534 (bottom right)—Same type of fracture as in fig 2533 with the exception that the anterolateral part of the tibia is broken off Treated by reduction with screw traction followed by continuous traction (fig 2544)

lateral dislocation of the foot (fig 2548) The violating force was already diminished when her right foot which was then tilted in supination reached the ground Therefore, the fragments are displaced to a lesser degree on the right side A supination adduction fracture (fig 2547) occurred on the right side The subsequent forward fall of the whole body caused bilateral shearing fractures of the anterior tibial wedge and bilateral forward and upward sub-



2527—2530 Sketched in October 1955

Top Row Impaction and Shearing Fractures in the Sagittal Plane
Bottom Row Impaction Shearing and Torsion Fractures in the Frontal and Sagittal Planes

FIG 2527 (top left) —Supination adduction or varus fracture with shearing off of the medial malleolus impaction of a small piece of the articular surface into the cancellous bone of the tibial metaphysis and avulsion of the tip of the lateral malleolus Treated with screw fixation (fig 2539 a)

FIG 2528 (top right)—Pronation abduction or valgus fracture with bending fracture of the lateral malleolus and lateral bending wedges caused by direct violence from the lateral side Depression of the lateral part of the articular surface An anterolateral part of the tibia has been sheared off Avulsion of the medial malleolus Non operative treatment (fig 2540 a)

FIG 2529 (bottom left) —Comminution fracture of the lower leg bones caused by impaction shearing and rotation following a fall of 1 M Fracture of a posterior wedge with postero cranial dislocation Varus 20° Treated by reduction through screw traction followed by continuous traction (fig 2545)

FIG 2530 (bottom right) —Comminution fracture of the lower leg bones caused by impaction shearing and rotation following a fall of 3 M An anterior bending wedge is broken off the middle part of the articular surface is depressed Anterior subluxation of the foot Varus 20° Treated by reduction with screw traction followed by continuous traction (fig 2546)



2537 November 8 1948 2537 a October 25 1955

Fig 2537 —Shearing off of a large posterior wedge the base of which includes half of the distal articular surface of the tibia and the medial malleolus The lateral malleolus too is sheared off Posterocranial dislocation of the foot The caput tali lies behind the anterior edge of the tibia Secondary valgus deformity of 35⁰ Sustained by a 58 year old woman (body height 168 cm weight 86 Kg) who fell on the road and came to sit on her heel (figs 2521/II a 2523) The posterior wedge was fixed with screws on the day of injury Three weeks later a lower leg walking cast was applied for another 7 weeks

Fig 2537 a —Same case seven years later Normal articular surface No arthrosis The posterior wedge fixed by two screws Free motion of toes Subtalar joint limited by one third Ankle joint 80⁰ to 120⁰ as against 80⁰ to 125⁰ on the right side Ankle joint not thickened Normal gait The 65 year old woman is asymptomatic



2538 February 18 1942 2538 a September 17 1955

Fig 2538 —Shearing off of a posterior wedge which consists of one third of the articular surface of the tibia The posterior part of the medial malleolus is also sheared off and is connected with the posterior wedge The preserved anterior part is clearly visible on the lateral picture The lateral malleolus is sheared off Pure posterior dislocation of the foot so that the injury may be overlooked in the anteroposterior roentgenogram Sustained by a 44 year old woman (165 cm 75 Kg) who slipped on a stairway Treatment manipulative reduction under local anesthesia Long leg cast which was split immediately throughout its full length One week later short leg walking cast for additional 9 weeks This fracture is stable as only one third of the articular surface of the tibia was sheared off

Fig 2538 a —Same case 13 years later The displacements can no longer be seen Free motion of toes Subtalar joint limited by one third ankle joint 75⁰ to 125⁰ as against 70⁰ to 130⁰ on the right side Normal gait Asymptomatic Had resumed his work which he performs in a standing position 5 months after the accident



2535 August 16 1952 2535 a October 16 1955

Fig 2535 —*Open* shearing off of a big anterior wedge with the medial malleolus broken off and anterocentral subluxation of the talus (fig 2525) Sustained by a 25 year old butcher who fell with his motorcycle Treatment Accurate wound excision reduction and screw fixation of both fragments long leg cast which was split immediately and followed two weeks later by a long leg walking cast for another 10 weeks

Fig 2535 a —Same case three years later The fracture dislocation has healed so well that the fracture lines are no longer visible No arthrosis Free motion of toes and subtalar joint Ankle joint 70° to 115° as against 70° to 125° on right side No swelling normal gait Slight pain only on vigorous exertion



2536 May 14 1949 2536 a March 19 1955

Fig 2536 —Impaction fracture at the lower end of the tibia with shearing off of a big anterior wedge which is broken into several pieces The medial malleolus is sheared off and an anterolateral wedge is broken off of the tibia The center part of the articular surface of the tibia is sheared off and displaced upward 20 mm Anterocranial subluxation of the foot (fig 2526) Sustained by a 30 year old plumber who fell 3 M from a roof Treatment Immediate fixation with screws cast which was split immediately three weeks later a long leg walking cast followed for nine weeks more

Fig 2536 a —Same case six years later The articular surface is restored Slight exostosis at anterior tibial edge The upper screw is too long Motion of toes free Subtalar joint limited by one third ankle joint 85° to 125° as against 75° to 135° on left side Slight pain only occasionally Normal gait Works again as a plumber

luxation of the foot Due to the great height of the fall fractures occurred in the sagittal and frontal planes with corresponding displacements

Shearing Fractures in the Sagittal Plane with Anterior Displacement of an



2537 November 8 1948 2537 a October 25 1955

Fig 2537—Shearing off of a large posterior wedge the base of which includes half of the distal articular surface of the tibia and the medial malleolus The lateral malleolus too is sheared off Posterocranial dislocation of the foot The caput tali lies behind the anterior edge of the tibia Secondary valgus deformity of 35° Sustained by a 58 year old woman (body height 168 cm weight 86 kg) who fell on the road and came to sit on her heel (figs 2521/II a 2523) The posterior wedge was fixed with screws on the day of injury Three weeks later a lower leg walking cast was applied for another 7 weeks

Fig 2537 a—Same case seven years later Normal articular surface No arthrosis The posterior wedge fixed by two screws Free motion of toes Subtalar joint limited by one third Ankle joint 80° to 120° as against 80° to 125° on the right side Ankle joint not thickened Normal gait The 65 year old woman is asymptomatic



2538, February 18 1942 2538 a September 17 1955

Fig 2538—Shearing off of a posterior wedge which consists of one third of the articular surface of the tibia The posterior part of the medial malleolus is also sheared off and is connected with the posterior wedge The preserved anterior part is clearly visible on the lateral picture The lateral malleolus is sheared off Pure posterior dislocation of the foot so that the injury may be overlooked in the anteroposterior roentgenogram Sustained by a 44 year old woman (165 cm, 75 kg) who slipped on a stairway Treatment manipulative reduction under local anesthesia Long leg cast which was split immediately throughout its full length One week later short leg walking cast for additional 9 weeks This fracture is stable as only one third of the articular surface of the tibia was sheared off

Fig 2538 a Same case 13 years later The displacements can no longer be seen Free motion of toes Subtalar joint limited by one third ankle joint 75° to 125° as against 70° to 130° on the right side Normal gait Asymptomatic Had resumed his work which he performs in a standing position 5 months after the accident

Anterolateral Wedge These fractures result from impaction in the long axis of the leg when the foot is in extreme pronation and dorsiflexion The anterior part of the lower end of the tibia which lies partly outside the articular surface is sheared off by the lateral edge of the trochlea tali and displaced forward (figs 2531, 2541) The same mechanism leads to anterolateral wedges at the epiphysis of juveniles (figs 2557, 2565, 2566)

Shearing and Impaction Fracture in the Sagittal Plane with Simultaneous Internal Rotation and Central Dislocation of the Foot This fracture results from a fall on a pronated and dorsiflexed foot shearing off a ventrolateral wedge The body, then, rotates toward the foot producing an internal torsion fracture of the tibia and a torsion fracture of the fibula Continuation of impaction in the long axis of the leg leads to central (cranial, upward) subluxation of the foot relative to the anterolateral wedge which has remained in place The lateral malleolus lies strikingly low (figs 2533—2534, 2543, 2544)

Shearing and Comminution Fractures Caused by a Vertical Fall, With Angulation but Without Rotation

These fractures occur from straight longitudinal impaction without simultaneous torsion in contrast to figures 2530, 2533, 2534, as when a person falls vertically on level (fig 2549) or sloping ground (figs 2548, 2550) The trochlea tali shears off an anterolateral wedge, disrupts the distal articular surface of the tibia and displaces the fragment in all directions A central (cranial) dislocation of the talus ensues If the pronated foot strikes on sloping ground, the fibula breaks too The talus then becomes displaced craniolaterally and is forced into severe valgus

Diagnosis of the various kinds of shearing and comminution fractures of the lower end of tibia and fibula is difficult without roentgenograms since severe swelling ensues soon after the accident Walking becomes impossible at once and pain is severe Among the definite signs of a fracture, displacement of the foot to the posterior, anterior, medial (or rarely to the lateral side), can be seen if this displacement is severe enough In comminuted fractures abnormal mobility and crepitation can be observed In the posterior shearing fractures the heel projects distinctly and the fore foot appears shortened In the anterior shearing fractures the heel is shortened and the fore foot is longer than usual There is also springy fixation, especially in cases with marked posterior or anterior dislocation

Complications It may prove difficult to maintain these fracture-dislocations in good position after reduction All muscles of the lower leg extensors as well as flexors, draw the foot upward and, depending on the type of fracture, also to the anterior (figs 2535, 2536), dorsal (figs 2537, 2538), medial (figs 2539, 2549) or lateral side (figs 2540 2548, 2550) because the concave lower articular surface of the tibia which normally holds the trochlea tali is disrupted Limitation of motion and painful arthrosis ensue if reduction is not accurate or if the good position achieved by reduction cannot be maintained until the fracture has united Varus deformity of 10° may cause much trouble in many a case, while cases with a valgus of 10° or even more may be asymptomatic Operative treatment may lead to infection

Avoidance of Complication After a thorough study of the roentgenograms the fracture should be reduced accurately and retention of the achieved good position should be maintained — by a cast, by continuous traction, or by open operation

Treatment of Shearing Fracture with Anterior Wedge

Diagnosis The severity of these fractures remains unrecognized in many cases If the anterior fragment is displaced as in figure 2524, the displacement is easily discernible If the fragment has been displaced parallel to the fracture plane as in figures 2525, 2535, the anterocranial displacement of the talus together with the foot is often overlooked and, therefore, not reduced If in doubt, comparison roentgenograms of the uninjured foot should be made

Treatment *Reduction* can usually be achieved under local anesthesia by strong plantar-flexion as the intact anterior ligaments of the ankle joint pull the anterior wedge back into its right place (figs 2624—2626)

Fixing the Anterior Wedge with Screws As reduction is easy, but retention of the good position in plaster or in traction is difficult, we usually perform open reduction and screw fixation The operation is performed under general or spinal anesthesia and in a bloodless field The fracture site is exposed through an anterior incision and the fragment is accurately reduced and fixed with one or two screws They should not be so long as to protrude at the other side of the bone (fig 2535 a) A cranially displaced intermediate fragment as in figures 2526, 2536, should be removed if it hinders accurate reduction The resulting small defect in the articular surface will cause no trouble if the main fragments are well reduced and the foot is not subluxated After operation a non-weight-bearing cast is applied for 2 to 3 weeks which is split immediately throughout its full length Three weeks later, a lower leg walking cast is applied which is retained until 12 weeks after the accident

Shearing Fractures with a Big Dorsal Wedge Treated in a Cast

Diagnosis If the foot is not only displaced cranio posteriorly as in figure 2538 but also medially or laterally as in figure 2537, the size of the sheared off wedge can be determined by roentgenograms only after reduction The foot should be internally rotated 20° for the anteroposterior as well as for the lateral roentgenogram, as shown in figures 2627, 2632, so that in the lateral projection the distal articular surface of the tibia and the trochlea tali are congruent In the anteroposterior roentgenogram, the medial joint space can be distinctly seen by this technique Extra-articular bone avulsions as occuring in pronation-external rotation fractures (figs 2687, 2688, 2695, 2696), do not belong to this group

Reduction *Time of Reduction* Complete reduction can usually be achieved in the first few hours only Later, the posterior dorsal wedge usually remains displaced upward by 1 to 2 mm

Local Anesthesia The ankle joint is rendered insensitive in the recumbent patient by injecting 20 cc of a 2% Novocain solution Pain disappears at once and muscle relaxation is complete

Positioning the Patient, and Reduction The knee of the recumbent or sitting patient (figs 2644—2650) is flexed to a right angle The foot is drawn downward and forward, as if pulling off a boot, and the ankle joint is dorsi flexed after the fragment has snapped into place The cranially displaced *posterior wedge is thus held down in place by means of the strong ligaments* connecting it with the talus and calcaneus (figs 2619, 2620)

Roentgenograms must be made in both projections to confirm complete reduction of the fragments and full correction of the dislocation This can only be determined if the foot is rotated inwards 20° at the time of the exposures (figs 2627—2632)

Immobilization in the Cast If the base of the dorsal wedge measures less than half the distal articular surface of the tibia (fig 2538), a hemp cord (see p 1656) is placed on the anterior side of the lower leg and a lower leg cast is applied The surgeon himself should hold the reduced foot in order to retain the reduced position, while the cast is applied by an experienced assistant The foot should be at a right angle to the lower leg

Roentgenograms When the cast has been applied, good roentgenograms should be made in both projections

Lengthening the Cast up to the Mid-Thigh As a lower leg cast which must be split does not give sufficient support to prevent re-dislocation of the foot, the cast is lengthened up to the mid thigh when the roentgenograms show good position At first a flannel strip is incised at intervals on one side (see p 1724 and placed round the thigh, then a 50 cm long plaster splint is applied at the posterior aspect, from the middle of the lower leg up to the middle of the thigh and a circular plaster bandage is wound over it Then a 75 cm plaster splint is cut into three parts of equal length o be placed on the medial, lateral and anterior sides of the knee joint Two circular plaster bandages are then applied

The *long leg cast* is *split immediately* and is *closed 2 to 3 days later* as described on page 1704

Roentgenograms When the swelling of the leg has disappeared 2 to 3 weeks later, roentgenograms focused on the ankle joint are made in both projections

Application of Long Leg Walking Cast If the roentgenograms show good position, a long leg walking cast is applied as described on pages 1724—1737

Then, new *roentgenograms* are made

If a slight posterior subluxation persists it must be abolished by holding the heel with one hand and exerting pressure upon the front of the supra-malleolar region with the other hand, the knee being flexed 90° This pressure and counterpressure must be maintained until the cast has hardened

Trimming the cast, cleaning the toes applying the walking stirrup marking the cast, and *exercises* are carried out as described on pages 1725—1731

Check Roentgenograms One week after application of the walking cast, then every other week, roentgenograms are made in both projections

Re-application of a Long Leg Walking Cast If the roentgenograms shows renewed posterior subluxation, re-reduction must be performed and a leg cast re-applied

Duration of Immobilization The cast is removed 10 to 12 weeks after the accident

Further treatment with the Unna's paste boot is carried out as in fractures of the shafts of the lower leg bones (see p 1733)

Results of Treatment It is surprising that, in spite of complete rupture of the anterior capsule and ligaments, the ankle joint becomes firm and regains an almost free range of motion, if reduction was complete and if immobilization has been maintained for a sufficient period of time (figs 2537, 2538) If reduction has not been complete or if renewed subluxation has resulted from too short an immobilization, limited motion and painful arthrosis will ensue, namely, just what some try to avoid by removing the cast prematurely

Treatment by Traction in Shearing Fractures with a Big Posterior Wedge

Formerly we reduced most shearing fractures with a big posterior wedge in the screw traction apparatus We, then, applied a lower leg cast which was split immediately and continued treatment by calcaneus pin traction Renewed subluxation occurred often Later we omitted the cast following reduction and used traction alone

For *traction treatment* the same is required as in a fracture of the shafts of tibia and fibula (see p 1705)

Treatment, with but small exceptions is carried out as in fractures of the shafts of the tibia and fibula (see pages 1704—1724)

If traction is used, it is expedient, first, to insert a calcaneus pin under local anesthesia and then, to carry out reduction manually as described on page 1829, to place the leg on a lower leg splint, and to apply 3 to 4 Kg traction

Bandaging the Lower Leg Splint The lower leg splint is bandaged like a Braun splint (see Vol II/p 1183) but with the difference that the bandages reach distal only as far as the middle of the lower leg A Bartmann pressure pad (fig 2375) is applied vertically on the anterior side of the lower leg

First Roentgen Check After carrying out reduction and positioning the leg, roentgenograms in 20° internal rotation (figs 2627—2632) are made in order to survey the joint space of the medial malleolus and that the distal articular surface of the tibia and the trochlea tali are congruent

Second Roentgen Check On the second day new roentgenograms are made in the same way If a cranial displacement of the posterior wedge should have occurred traction is increased by 1 Kg If diastasis in the ankle joint has occurred, traction is decreased by 1 Kg

Third Roentgen Check Should displacement have occurred, new roentgenograms are made the day following the changing of the traction weights Otherwise new roentgenograms are made each following week

Application of the Lower Leg Walking Cast Four weeks later a lower leg walking cast is applied for further six weeks

Fourth Roentgen Check New roentgenograms in both projections are made in the walking cast

Further treatment in the Unna s paste boot is the same as in fracture of the shaft of the tibia and fibula (see p 1733)

As to the *roentgenograms*, *exercises* following *removal of the walking cast*, *massage*, *passive motion*, and *final roentgen check* at the end of the treatment, the same applies as in fractures of the shafts of tibia and fibula (see p 1734)

Figures 2691—2694, show that good end results can be achieved after complete reduction

Questions We Should Ask Ourselves in Order to Avoid Failures When Treating Shearing Fractures with a Big Posterior Wedge by Traction

In addition to the question given on pages 1715—1717 and 1718—1724 the following questions should be answered

1 Has the lower leg splint been bandaged only to the middle of the lower leg
2 Have I, after insertion of the calcaneus pin performed reduction as described on pages 1829, 1830?
3 Have I used 4 kg instead of 3 kg for longitudinal traction?
4 Have I applied a well-lined Bartmann pad (fig 2375) vertically to the anterior side of the lower leg?
5 Have I, after reduction, positioning on the lower leg splint, application of 4 kg traction and attachment of the Bartmann pad, made roentgenograms in both projections at 20° internal rotation in order to survey the joint space of the medial malleolus in the anteroposterior view and the joint space between the tibia and the talus in the lateral view?
6 Have I repeated the roentgenograms on the next day?
7 Have I increased the traction weight in cranial displacement of the posterior wedge?
8 Have I decreased the traction weight in the case of diastasis in the ankle joint?

Operative Treatment by Screw Fixation in Shearing Fractures with a Big Posterior Wedge

Indication for Operation If half of the distal articular surface of the tibia has been sheared off or a bone splinter lies between the main fragments and hinders accurate apposition, the fracture should be exposed for insertion of a screw

Time of Operation The most suitable time lies within the first few hours after the accident when no big swelling has yet developed Otherwise, the operation must be delayed for 8 to 10 days until the swelling has disappeared and the skin has become normal If operation is performed later, arthrosis will, in most cases, develop as soon as after a few years

The operation is performed under general or spinal anesthesia and in a bloodless field

Application of the Tourniquet A bloodless field is necessary for a good survey of the fracture and for a rapid operation

Insertion of the Calcaneus Pin The calcaneus pin is inserted as described on page 1707 and the rotation stirrup and the protective cap are applied

Positioning the Patient After insertion of the pin the patient is placed in a prone position in such a way that the foot reaches below the edge of the table and can thus be freely dorsiflexed

Exposure of the Bone and Reduction of the Fragments The fracture is exposed through a longitudinal incision at the lateral side of the Achilles tendon The latter should not be severed in a Z shape as thread fistulae may occur and infection may spread down to the site of fracture When the fracture has been exposed, traction is applied at the calcaneus pin After correction of the shortening the foot is dorsiflexed The fracture margins must be accurately apposed

Splinters lying between the main fragments must be removed Damage to the margins of the posterior wedge must be avoided lest accurate apposition of the fragments become difficult without opening the joint

Insertion of a Drill, and Check Roentgenogram When accurate apposition of the fragments has been achieved, the wedge is held fast with a raspatory and a thick enough drill is inserted at right angles to the bone surface Roentgenograms are made in both projections at a 20° internal rotation If the roentgenograms have not been taken at the proper angles, they must be repeated until the joint space is clearly discernible from both sides (figs 2627, 2630)

Insertion of a Second Drill When the first drill is well in place, a second drill is inserted parallel to the first one The drills should be placed at least 5 mm distant from the joint space

Determining the Length of the Screw A screw should be chosen, 5 mm less in length than the distance between the posterior and anterior tibial cortices measured in the roentgenogram at the level of the drill The screw should not reach beyond the anterior cortex (fig 2537 a)

Insertion of the Screws After removal of the first drill the first screw is inserted Then the second drill is removed and the second screw inserted

Roentgenograms When both screws have been inserted new roentgenograms are made prior to closure of the wound (fig 2537)

If the medial malleolus is still displaced after open reduction and fixation of the posterior wedge, the malleolus should be exposed through a transverse incision, then reduced with a single-pronged bone hook and fixed to the tibia by two crossed wires (figs 2716, 2733, 2734)

Application of a Compression Bandage and Lower Leg Cast After closure of the wound a sterile hemp cord is placed on the anterior side of the lower leg When a compression bandage has been applied the tourniquet is removed and a lower leg cast applied which is split throughout its full length

Application of a Lower Leg Walking Cast Three weeks later a lower leg walking cast is applied for further seven weeks

Further Treatment is carried out as in fractures of the shafts of the tibia and fibula (see p 1733)

Treatment with Crossed Wires in Shearing Fractures with a Big Posterior Wedge

Reduction is performed in the short screw traction apparatus (see p 1710 and figs 2410, 2411) If proper roentgenograms show good position of the fragments without a step of the articular surface and without subluxation, the big posterior wedge can be fixed to the tibia percutaneously from the posterior side by two crossed wires A lower leg cast is applied which is split immediately

followed by a lower leg cast 2 to 3 weeks later We use this treatment rarely because it is difficult and may necessitate much fluoroscopy

Questions We Should Ask Ourselves in Order to Avoid Failures When Fixing a Posterior Wedge by Screws

1 Have I used screws for fixation of a posterior wedge which is bigger than half the lower articular surface of the tibia?
2 Have I exposed and reduced a posterior wedge if small splinters lying in the fracture cleft hindered accurate reduction?
3 Have I operated within the first few hours before a big swelling has developed or 8 to 10 days later when the swelling has subsided?
4 Have I operated in bloodless field for better visibility?
5 Have I inserted a calcaneus pin for reduction?
6 Have I, after application of a tourniquet and insertion of calcaneus pin placed the patient in a prone position in such a way that the foot reaches beyond the edge of the table and can be dorsiflexed freely?
7 Have I incised the skin lateral to the Achilles tendon without severing it in order to avoid suture fistulae?
8 Have I exposed the fragments at the cranial margin of the posterior wedge and reduced the fracture by traction on the pin and simultaneous dorsiflexion?
9 Have I after accurate reduction and insertion of a drill, made roentgenograms in both projections at a 20° internal rotation?
10 Have I, in order to confirm accurate reduction, repeated the roentgenograms, if the joint space at the medial malleolus in the anteroposterior view (fig 2627) and the joint space below the tibia in the lateral view (fig 2630) are not clearly visible?
11 Have I inserted the screws at least 5 mm distant from the talocrural joint?
12 Have I made new roentgenograms after insertion of the second screw and before closure of the skin?
13 Have I after closing the skin and positioning a sterile hemp cord, applied a compression bandage and over it a lower leg cast?
14 Have I immediately split the cast throughout its full length?

End-results of Impaction Fractures with Shearing-off of a Big Posterior Wedge

In the 27 years from 1926 to 1952 we treated 122 fresh and 88 old cases of fracture dislocation with a big dorsal wedge broken off 43 were treated with a cast alone, 10 with cast and traction 47 with traction and 22 by open operation Trojan[1] re-examined 90 (73 8%) of these 122 cases 1 to 24 years after the accident Of 32 patients with slight primary displacement two whose fractures had united with subluxation showed severe arthrosis with pain and pronounced limitation of motion 9 and 24 years after the accident Four patients had moderate arthrotic signs and slight pain 13 to 23 years after the accident, 32 patients re-examined a relatively short time after the accident, had no arthrosis

[1] Trojan E Ztschr Orth u Grenzgebiete *84* 636—644

Of 52 cases with marked displacement 14 had a severe arthrosis which developed about 10 years after the accident Many patients complained of relatively slight pain in spite of severe arthrotic changes The walking capacity in patients with cranial displacement of the posterior wedge by 1 to 2 mm is good, if the foot is not subluxated posteriorly Among operated cases arthrosis developed particularly in patients whose operation was unduly delayed

Treatment of Fractures Sheared Off in the Sagittal Plane to the Medial Side (Supination or Adduction Fractures) or to the Lateral Side (Pronation or Abduction Fractures)

Fractures sheared off in the sagittal plane to the medial (figs 2527, 2539) or to the lateral side (figs 2528, 2540) differ from equivalent malleolar fractures (figs 2683—2686) in that the traumatizing force was strong enough to depress the medial or lateral side of the articular surface of the tibia, in addition to the malleolar fracture Treatment is the same as in fracture of the ankle and will be described later It is as a rule, conservative Only in open fractures is osteosynthesis with screws (fig 2539) or crossed wires (figs 2716, 2733, 2734) recommended

Treatment of Sagittal Shearing and Impaction Fractures with an Anterolateral Wedge [1]

Origin An anterolateral wedge is sheared off from the lower end of the tibia (figs 2531, 2541) if violence acts on an extremely pronated and dorsiflexed foot If the violence continues and the body rotates towards the foot, an additional internal rotation fracture of the tibia occurs The resulting large torsion wedge of the tibia consists of more than half of the articular surface and is, by impaction, displaced upwards (cranially) in the long axis of the tibia (fig 2533) The fibula remains intact in some cases (fig 2544) and breaks in others (figs 2542, 2543) In cases, where there is no torsion, and where the force acts in the long axis alone, the trochlea tali shatters the lower end of the tibia This may (fig 2549) or may not be (figs 2548, 2550) accompanied by a fractured fibula

Diagnosis The typical signs of this fracture namely, the anterolateral wedge which remains in its place and the cranial subluxation of the talus are often overlooked These possibilities must therefore be borne in mind in all fractures of the lower end of the tibia

Treatment In the extraordinarily rare case of an isolated anterolateral wedge with marked displacement, open reduction and fixation by screws (fig 2541) — or better, by crossed wires — should be performed

Treatment of the Comminuted Fractures by Traction

The same equipment is necessary as for a fracture of the shafts of the tibia and fibula The fracture and the dislocation are reduced under local anesthesia in the screw traction apparatus with a traction weight of 6 to 8 kg

[1] Trojan E Revue Chir Orthop 1956



2539 May 23 1954 2539 a September 16 1954

FIG 2539—*Open* supination adduction or varus fracture with shearing off of the medial malleolus depression of the central part of the articular surface into the spongy bone of the metaphysis Avulsion of the tip of the lateral malleolus mediocranial dislocation of the talus (fig 2527) Sustained by a 55 year old woman in a motorcycle collision Treatment accurate wound excision under local anesthesia *reduction fixation with screws drain* skin *suture* long leg cast which was split immediately four weeks later long leg walking cast for another eight weeks

FIG 2539 a—Dislocation fracture healed in perfect position The impression near the medial malleolus clearly visible



2540 July 30 1951 2540 a October 31 1951

FIG 2540—Pronation abduction or valgus fracture of the lateral malleolus with multiple bending wedges An anterolateral wedge has been sheared off from the lower end of the tibia Depression of the lateral part of the articular surface of the tibia Avulsion of the medial malleolus with lateral subluxation Sustained in a 5 M fall from a hay wagon (fig 2528) Treatment manual reduction under local anesthesia short leg cast which was split immediately one week later short leg walking cast for another twelve weeks

FIG 2540 a—Same case 13 weeks after the accident after removal of the cast Fracture dislocation has united with slight valgus Five months after the accident the patient walked with a slight limp Tendency to swelling Toes and subtalar joint limited by half ankle joint 80° to 105° as against 70° to 110° on the uninjured side

(*figs 2410, 2411*) Traction must be applied until the distal articular surface of the tibia has been pulled down to the level of the lateral wedge This can usually be achieved by traction with 6 to 8 Kg If the roentgenograms focused on the ankle joint, show that the position is good and that the subluxation has disappeared, the leg is placed on a lower leg splint and traction is weighted



2541 April 5 1953 2541 a April 29 1953

FIG 2541 —An anterolateral wedge has been sheared off of the tibia The lateral part of the anterior margin of the lower end of right tibia has been impressed and displaced laterally (see fig 2531) On the left tibia the whole anterior margin has been sheared off Sustained by a 30 year old woman passenger in the side car of a motorcycle with her foot dorsiflexed and pronated Screw fixation three weeks after the accident Three weeks later a lower leg cast was applied for another six weeks

FIG 2541 a —Same case after operation Good position of the fragment the malleolar fork is closed No arthrosis two years later Free motion of toes motion of subtalar joint limited by one third bilaterally both talocrural joints limited 95° to 120° on right side 90° to 120° on the left side No swelling Normal gait Slight pain when the weather changes



2542 December 24 1937 2542 a January 22 1955

FIG 2542 —Impaction and torsion fracture at the distal end of the right lower leg with a large torsion wedge and dorsocranial subluxation of the talus The anterolateral edge of the tibia has remained intact (see fig 2533) Sustained by a 38 year old servant who slipped and fell on the road Reduction in the screw traction apparatus application of a long leg cast which was split at once continuous traction weighted with 5 Kg for 6 weeks followed by a long leg walking cast for another 6 weeks

FIG 2542 a —Same case 17 years later The articular surfaces have regained normal shape Good alignment slight arthrosis of the ankle joint moderate trouble

with 4 to 5 Kg (not 2 to 3 Kg as for fractures of the shafts) Further treatment with traction is performed as in fractures of the shafts (see pp 1704—1717) If the displacements are not very marked, the leg may be placed on a lower leg splint immediately after insertion of the calcaneus pin and reduction may be performed manually under adequate longitudinal traction



2543 November 25 1954 2543 a October 22 1955

FIG 2543 —*Fracture of the tibia and fibula caused by impaction and rotation An anterolateral* wedge is sheared off from the tibia but has remained in connection with the fibula The other fragments of the tibia together with the talus have been subluxated 6 mm upward Varus of 10° at the tibia varus of 15° at the fibula Sustained by a 30 year old merchant who fell out of a street car Treatment reduction under local anesthesia in the screw traction apparatus continuous traction weighted with 4 kg for 5 weeks followed by a long leg walking cast for 7 weeks

FIG 2543 a —Same case 11 months later Fracture united in good position No step in the joint surface *Ankle region still thickened Normal gait* Free motion of toes subtalar joint limited by one third talocrural joint 82° to 115° as against 78° to 120° right



2544 December 27 1949 2544 a March 23 1955

FIG 2544 —Isolated fracture of the tibia caused by impaction and torsion An anterolateral wedge was sheared off from the tibia This wedge remained in connection with the fibula but was pushed forward Long torsion fracture of the tibia The main fragment of the tibia together with the talus was subluxated 12 mm cranially Sustained by a 29 year old unskilled worker who fell 3 M from a ladder Treated by reduction and fixation with wire loops and a screw

FIG 2544 a —Same case 5 years later Bony union in perfect position Joint surface reconstructed No arthrosis Free motion of the toes subtalar joint limited by 25% talocrural joint 85° to 120° as against 80° to 140° on left side Normal gait Almost trouble free



2545 February 27 1940 2545 a January 27, 1955

FIG 2545 —*Open* comminuted fracture at the lower end of the *tibia caused by impaction* shearing flexion and torsion Shearing off of a posterior wedge avulsion of the medial malleolus torsion fracture of the tibia with varus of 20° (fig 2529) Sustained by a 52 year old man who fell 1 M from a scaffolding Treatment consisted of accurate wound excision drain suture of the skin and the skin only calcaneus pin reduction in the screw traction apparatus long leg cast which was split and windowed immediately continuous traction weighted with 5 Kg for 3 weeks and long leg walking cast for an additional 9 weeks

FIG 2545 a —Same case 15 years later Bony union in good position No arthrosis Free motion of toes subtalar joint limited by 50/ talocrural joint 85° to 100° as against 75° to 110° on the uninjured side Ankle region slightly thickened Normal gait Pain only on exertion



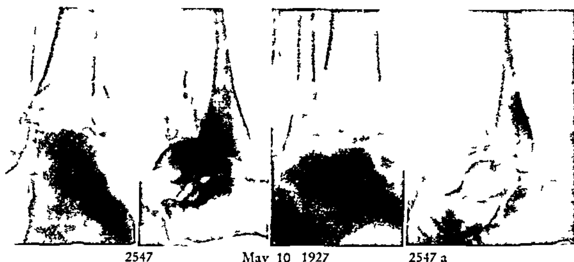
2546, August 1 1939 2546 a January 22 1945

FIG 2546 —Comminuted fracture at the lower end of the lower leg bones caused by impaction shearing torsion and flexion Anterior wedge sheared off from the tibia depression of a central part of the joint surface avulsion of the medial malleolus anterocranial subluxation Varus of 15° (fig 2530) Sustained by a 57 year old carpenter who fell 3 M from a ladder Treated by reduction in the *screw traction apparatus and continuous traction with* 5 Kg for 6 weeks Long leg walking cast for another 6 weeks

FIG 2546 a —Same case 15½ years later Excellent position of the fragments Joint space *narrowed no* arthrosis Severe demineralization due to old age Only shaky movements in the subtalar joint motion of talocrural joint 85° to 100° as against 75° to 120° on the left side Can walk well feels pain at intervals only

Further treatment is also carried out as in fractures of the shafts (see pp 1717—1724) On the next day roentgenograms focused on the ankle joint must be made and studied carefully lest subluxation or angulation be over looked

Duration of Immobilization in Traction Traction should be maintained for 5 to 6 weeks (not 3 to 4 weeks as in fractures of the shafts) A long leg walking cast is then applied for 6 weeks as described on pages 1724—1731



FIGS 2547 2548—Impaction and shearing off fracture at the distal end of both lower legs Sustained by a 32 year old female by a fall from the 2nd floor (attempted suicide) She probably landed on a slope at first with the left then with the right foot Thus the traumatizing force the comminution and the displacements were greater on the left side than on the right side The left foot was forced into a position of pronation abduction or valgus the right foot into supination adduction or varus

FIG 2547—Shearing off of an anterior wedge and of the medial malleolus with antero medio cranial subluxation of the right talus The fibula has remained intact Compare figs 2522 2535 2536

FIG 2547 a—Same case after reduction under local anesthesia and application of a cast Both fragments and the subluxation have been well reduced These fracture dislocations can only be retained in good position by the use of screws (compare figs 2535 2536)

Treatment by Osteosynthesis If reduction cannot be achieved manually or in the screw traction apparatus, open reduction is performed by calcaneus pin traction and the fragments are fixed with wire loops or screws (fig 2544) Operative reduction is especially indicated in old cases Three to four weeks later a long leg walking cast is applied This will be retained until ten weeks after the injury

Treatment of Fractures Caused by Shearing and Impaction with Simultaneous Internal Rotation

These fractures can be reduced comparatively easily under local anesthesia by calcaneus pin traction or by manipulation Further treatment is carried out by continuous traction for 5 to 6 weeks followed by a long leg walking cast Slight varus deformity as in figure 2545 will remain in some case

If an intermediate bone wedge in the center of the joint cannot be reduced as shown in figure 2546, no trouble will arise as long as the main fragments are well reduced

Treatment of Fractures Caused by Shearing and Comminution, Showing Angulation but No Rotation

The apparently irregular splinters can be reduced under local anesthesia by longitudinal traction and manipulation (fig 2548 a) or in the screw traction apparatus The fragments usually become well aligned as the better part of the periosteum has been preserved A diastasis must be created in the ankle joint



2548 May 10 1927 2548 a

Fig 2548 —Comminuted fracture at the distal end of the left tibia and fibula with shearing off of a big anterior wedge torsion fracture of the tibia comminuted fracture of the lateral malleolus and anterolateral dislocation of the talus Valgus of 50°

Fig 2548 a —Same case after manual reduction under local anesthesia and application of a cast All fragments and the dislocation have been well reduced Good position in these severe fracture dislocations can only be retained by continuous traction (fig 2549) or by cast with two pins or wires incorporated (figs 2447—2457) If the anterior wedge is as big as in this case it may also be fixed with screws

as in figure 2550 a If the fragments remain separated, they are pressed together manually If the main fragments are well reduced medially and laterally, walking capacity will be good even if a part of the articular surface lies oblique as in figure 2550 a

Further treatment is carried out by continuous traction weighted with 4 to 5 kg The next day, roentgenograms focused on the ankle joint must be made to confirm that the good position has been retained If too small weights are used the talus becomes re displaced upward and drives the fragments apart (figs 2550 b, c) If heavy enough traction has been exerted through a long enough period of time, union will be achieved in a satisfactory position (fig 2549 c) Continuous traction as described on pages 1704—1724 must be maintained for 6 weeks After that a long leg walking cast for another 6 weeks follows



2549 August 9 1947 2549 a March 18 1955

FIG 2549—Severely comminuted fracture at the lower end of the left tibia A relatively big anterolateral wedge has been sheared off from the tibia This wedge has remained in connection with the fibula as in figs 2526 2534 2536 2544 Mediocranial dislocation of the talus which has sheared off the medial malleolus similarly as in fig 2536 It is tilted over the medial edge of the talus The tibia is split in the frontal plane The posterior part of its articular surface has been driven out posteriorly Sustained by a 56 year old farmer who fell 3 M from a roof Treated by reduction under local anesthesia followed by traction weighted with 4 Kg for 4 weeks and a long leg walking cast for another 8 weeks

FIG 2549 a—Same case 7½ years later Bony union of the fragments in good position the subluxation has been abolished Only slight arthrotic exostoses Free motion of toes subtalar joint limited by 25/ talocrural joint 80° to 115° as against 75° to 125° on the right side Asymptomatic Normal gait

Questions We Should Ask Ourselves in Order to Avoid Failures When Treating Shearing and Impaction Fractures

1 Have I good roentgenograms been taken, well focused on the ankle joint?
2 Have I carefully studied the roentgenograms and especially looked for an anterolateral wedge?
3 Have I reduced manually or in the screw traction apparatus?
4 Have I used weight traction of 4 to 5 Kg (not 2 to 3 Kg as in fractures of the tibial and fibular shafts) in order to produce a 4 to 5 mm diastasis in the talocrural joint?
5 Have I taken check roentgenograms every other day and later on every other week? Have I increased or decreased the traction weights according to need?
6 Have I kept up continuous traction for six weeks?
7 Have I answered the questions on pages 1715 and 1718 regarding application of traction and further treatment?
8 Have I, after six weeks, applied a long leg walking cast for another six weeks?
9 Have I answered the questions on page 1735 about application of a long walking cast?

105 SEPARATION OF THE LOWER TIBIAL AND FIBULAR EPIPHYSES

Separation of the lower tibial and fibular epiphyses occurs from the 2nd to the 18th year of life There are four different types Bartl[1] has surveyed

1 Bartl Die traumatische Epiphysenlosung am distalen Tibiaende 54 Heft zur Monatsschr *Unfallheilk* 1956



2550 September 1 1936 — 2550 a September 1 1936
2550 b December 17 1936 — 2550 c January 20 1955

Fig 2550.—Severe comminution fracture at the distal end of the lower leg with shearing off of an anterolateral wedge from the tibia The wedge has remained connected with the fractured fibula as in fig 2549 The fibula broke when the talus was displaced craniolaterally Avulsion of the medial malleolus The distal part of the tibial articular surface was displaced posteriorly Sustained by a 45 year old unskilled worker who fell 4 M from a freight car

Fig 2550 a.—Same case during reduction in the screw traction apparatus weighted with 9 Kg Dislocation and shortening have disappeared since the anteroposterior roentgenogram shows that the medial malleolus has been pulled down to the level of the anterolateral wedge The A P roentgenogram shows that a part of the articular surface is oblique There is a 4 to 5 mm diastasis in the joint In the lateral roentgenogram the fragments are still displaced slightly posteriorly together with the talus In this state a plaster was applied and split immediately Continuous traction of 4 Kg was applied for five weeks

Fig 2550 b Same case 15 weeks later upon removal of the cast As the traction weight of 4 Kg was too slight for a patient in plaster re shortening and separation of the fragments in the frontal and sagittal planes occurred after 10 days The tibial articular surface is irregular in the lateral roentgenogram

Fig 2550 c.—Same case 18½ years later Bony union with good alignment though with broadening in the sagittal and frontal planes Severe marginal exostoses at the posterior and anterior sides The articular space seems to have vanished in the a p roentgenogram as it is overlain by thick marginal exostoses It shows normal width in the lateral roentgenogram The irregularities shown in fig 2550 b have disappeared Toes freely mobile the subtalar joint is limited by 75% Talocrural joint 85° to 95° as against 80° to 120° on the right side Patient walks normally he feels pain only after overexertion

Figs 2551—2556 sketched in October 1954



2549 August 9 1947 2549 a March 18 1955

Fig 2549—Severely comminuted fracture at the lower end of the left tibia A relatively big anterolateral wedge has been sheared off from the tibia This wedge has remained in connection with the fibula as in figs 2526 2534 2536 2544 Mediocranial dislocation of the talus which has sheared off the medial malleolus similarly as in fig 2536 It is tilted over the medial edge of the talus The tibia is split in the frontal plane The posterior part of its articular surface has been driven out posteriorly Sustained by a 56 year old farmer who fell 3 M from a roof Treated by reduction under local anesthesia followed by traction weighted with 4 Kg for 4 weeks and a long leg walking cast for another 8 weeks

Fig 2549 a—Same case 7½ years later Bony union of the fragments in good position the subluxation has been abolished Only slight arthrotic exostoses Free motion of toes subtalar joint limited by 25/ talocrural joint 80° to 115° as against 75° to 125° on the right side Asymptomatic Normal gait

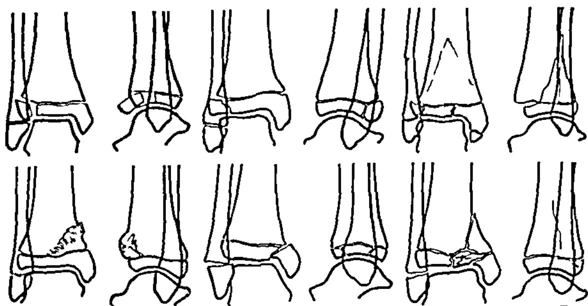
Questions We Should Ask Ourselves in Order to Avoid Failures When Treating Shearing and Impaction Fractures

1 Have I good roentgenograms been taken, well focused on the ankle joint?
2 Have I carefully studied the roentgenograms and especially looked for an anterolateral wedge?
3 Have I reduced manually or in the screw traction apparatus?
4 *Have I used weight traction of 4 to 5 Kg (not 2 to 3 Kg as in fractures* of the tibial and fibular shafts) in order to produce a 4 to 5 mm diastasis *in the talocrural joint?*
5 Have I taken check roentgenograms every other day and later on every other week? Have I increased or decreased the traction weights according to need?
6 Have I kept up continuous traction for six weeks?
7 Have I answered the questions on pages 1715 and 1718 regarding application of traction and further treatment?
8 Have I, after six weeks applied a long leg walking cast for another six weeks?
9 Have I answered the questions on page 1735 about application of a long walking cast?

105 SEPARATION OF THE LOWER TIBIAL AND FIBULAR EPIPHYSES

Separation of the lower tibial and fibular epiphyses occurs from the 2nd to the 18th year of life There are four different types Bartl[1] has surveyed

[1] Bartl Die traumatische Epiphysenlosung am distalen Tibiaende 54 Heft zur Monatsschr Unfallheilk 1956



Figs 2557—2562 sketched in October 1954

Fig 2557 top left—Avulsion of an anterolateral wedge of the epiphysis The bone wedge has been pushed anterolaterally Sustained by extreme dorsiflexion and pronation as in figs 2531, 2566

Fig 2558 top center—Avulsion of a posterolateral wedge of the epiphysis Slight displacement

Fig 2559 top right—Separation of the lower tibial epiphysis avulsion of a big posterior bone wedge The epiphysis is broken in three places Posterior displacement

Fig 2560 bottom left—Supination fracture of the metaphysis extending to the epiphyseal line Slight degree of varus and recurvation Growth may be disturbed if the varus angulation is not corrected

Fig 2561 bottom center—Supination fracture of both malleoli The medial malleolus is broken at the epiphyseal line the lateral malleolus is avulsed in the epiphyseal line Medial displacement of the foot Growth will be disturbed if the displacement is not corrected completely (figs 2571—2573)

Fig 2562 bottom right—Lower tibial epiphyseolysis with comminution of the medial part of the epiphysis A bone wedge is sheared off of the medial part of the metaphysis Fibular epiphyseolysis The comminuted medial part of the tibial epiphysis is compressed and driven into the metaphysis Lateral gap of the fibular epiphysis *The lateral concavity of the lateral malleolus has disappeared* Sustained by supination as in figs 2527 2539

4 Epiphyseolysis with fracture of the epiphysis and the diaphysis (33 = 14 2% figs 2559, 2562, 2567)

Origin and Types of Fracture Just as fractures of the lower ends of the tibia and fibula in adults epiphyseolysis usually results from indirect force, i e, slipping falling catching on an obstacle Among our cases, Bartl found 19 6% which resulted from direct force, e g, the impact of heavy objects or a patient being caught by a rope (fig 2570)

Four types of displacement are encountered

1 Epiphyseolysis with varus deformity,
2 Epiphyseolysis with valgus deformity,
3 Epiphyseolysis with antecurvature (angle being open (concave) posteriorly),
4 Epiphyseolysis with recurvation (angle being open (concave) anteriorly),

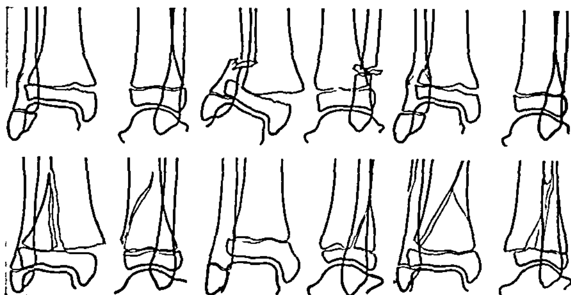


FIG 2551 top left—Pure separation of the lower tibial epiphysis with slight gaping medially Lateral displacement of 2 mm Subperiosteal fibular fracture at the same level Valgus of 10° Sustained by pronation and abduction as in the case of fig 2528

FIG 2552 top center—Pure separation of the lower tibial epiphysis Flexion fracture of the fibula at a slightly higher level than in fig 2551 Valgus of 30° Lateral displacement of the tibial epiphysis by a third of the width of its shaft Lateral displacement of the fibula by the full width of its shaft Bending wedge broken out of the fibula Sustained by pronation as in the case of fig 2528 The violence has been greater than in fig 2551

FIG 2553 top right—Separation of the lower tibial epiphysis A small wedge has been sheared off from the lateral part of the metaphysis Medial gap Lateral displacement of 2 mm Subperiosteal fibular fracture at the same level Sustained by pronation as in fig 2551

FIG 2554 bottom left—Separation of the lower tibial epiphysis with big lateral torsion wedge broken from the diaphysis Intact fibula Valgus of 15° Lateral displacement by a fourth of the width of the shaft Sustained by pronation and internal rotation

FIG 2555 bottom center—Loosening of the lower tibial epiphysis A small dorsal wedge is sheared off from the metaphyseal region Slight gap at the anterior side slight dorsal displacement intact fibula Sustained by forced plantar flexion as in figs 2521 2523 2537 2538

FIG 2556 bottom right—Separation of the lower tibial epiphysis with a 11 cm long posterior wedge broken from the tibial diaphysis Sustained by external rotation of the body while the foot was fixed on the floor Thus the foot was rotated internally Posterior displacement of the torsion wedge and the epiphysis as in fig 2564

FIGS 2551—2562 2565 2569 are taken from Bartl s[1] paper

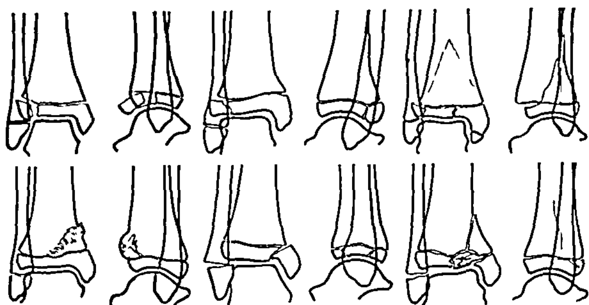
our 232 cases treated in the 26 years from the beginning of 1928 to the end of 1953

Classification

1 Pure separation of the epiphysis (87 = 37 5% figs 2551, 2552, 2563)
2 Epiphyseolysis with fracture of the diaphysis (83 = 35 8%, figs 2553—2556 2560 2564, 2569, 2570)
3 Epiphyseolysis with fracture of the epiphysis (29 = 12 5% figs 2557, 2558, 2561, 2565 2566 2571—2572)

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1 Bartl Die traumatische Epiphysenlosung am distalen Tibiaende 54 Heft zur Monatsschr Unfallheilk 1956



FIGS 2557—2562 sketched in October 1954

FIG 2557 top left —Avulsion of an anterolateral wedge of the epiphysis The bone wedge has been pushed anterolaterally Sustained by extreme dorsiflexion and pronation as in figs 2531 2566

FIG 2558 top center —Avulsion of a posterolateral wedge of the epiphysis Slight displacement

FIG 2559 top right —Separation of the lower tibial epiphysis avulsion of a big posterior bone wedge The epiphysis is broken in three places Posterior displacement

FIG 2560 bottom left —Supination fracture of the metaphysis extending to the epiphyseal line Slight degree of varus and recurvation Growth may be disturbed if the varus angulation is not corrected

FIG 2561 bottom center —Supination fracture of both malleoli The medial malleolus is broken at the epiphyseal line the lateral malleolus is avulsed in the epiphyseal line Medial displacement of the foot Growth will be disturbed if the displacement is not corrected completely *(figs 2571—2573)*

FIG 2562 bottom right —Lower tibial epiphyseolysis with comminution of the medial part of the epiphysis A bone wedge is sheared off of the medial part of the metaphysis Fibular epiphyseolysis The comminuted medial part of the tibial epiphysis is compressed and driven into the metaphysis Lateral gap of the fibular epiphysis *The lateral concavity of the lateral malleolus has disappeared* Sustained by supination as in figs 2527 2539

4 Epiphyseolysis with fracture of the epiphysis and the diaphysis (33 = 14 2%, figs 2559, 2562 2567)

Origin and Types of Fracture Just as fractures of the lower ends of the tibia and fibula in adults epiphyseolysis usually results from indirect force i e, slipping falling, catching on an obstacle Among our cases Bartl found 19 6% which resulted from direct force e g the impact of heavy objects or a patient being caught by a rope (fig 2570)

Four types of displacement are encountered

1 Epiphyseolysis with varus deformity,
2 Epiphyseolysis with valgus deformity,
3 Epiphyseolysis with antecurvature (angle being open (concave) posteriorly),
4 Epiphyseolysis with recurvation (angle being open (concave) anteriorly),

This classification is important for treatment

The separation of the epiphysis always occurs between the metaphyseal bone and the epiphyseal cartilage Thus the epiphyseal cartilage remains connected with the epiphysis

Epiphyseolysis with varus deformity (figs 2560—2562, 2567, 2571—2573) is not the most common but is a very important group Disturbed growth may follow inaccurate reduction These cases result from supination Characteristically the fibular epiphysis is separated too and becomes more or less displaced medially together with the talus If the acting force is slight, the fibular epiphysis is separated and the medial malleolus is sheared off in the epiphyseal line (figs 2561, 2571, 2572) Figure 2571 shows a gap between the talus and the medial malleolus The latter is tilted medially, a sign that the talus together with the lateral malleolus was displaced further medially at the moment of the accident but did not completely return into its old place The medial malleolus remained displaced because it was caught on a spur *If the lateral concavity of the lateral malleolus is absent, it is a sign of displacement of the lateral malleolus In case of displacement, the lateral contour of the lateral malleolus may be straight or even convex* (figs 2561, 2562, 2567, 2572) The extent of displacement and angulation of the lateral malleolus can be clearly seen in the sketch of figure 2567 In the case of greater violence, in addition to lower fibular epiphyseolysis, the medial malleolus is also sheared off, the medial third of the epiphysis is depressed into the metaphysis and a medial wedge is sheared off from the metaphysis (figs 2562, 2567) as in figures 2527 2539 *Epiphyseolysis caused by supination will disturb normal growth unless the varus deformity is corrected completely* (figs 2571—2573, 2576)

Fibular epiphyseolysis occurs only in supination-adduction fractures with varus In all other kinds of lower tibial epiphyseolysis the fibula either remains intact (figs 2554, 2555, 2557, 2558, 2565, 2566) or it breaks proximal to the epiphyseal plate (figs 2551—2553 2556, 2559, 2563, 2564, 2569, 2570)

Epiphyseolysis with valgus deformity (figs 2551—2554, 2563) is caused by pronation-abduction Separation of the medial side of the tibial epiphysis is combined with a bending fracture of the fibula at the level of the tibial epiphysis (figs 2551 2553) or slightly higher producing a laterally open angle (figs 2552 2563) In the case of a small traumatizing force the separation at the medial side of the epiphyseal plate will be slight and the fibular fracture is of the "greenstick type (fig 2551) With greater violence the separated tibial epiphysis and the distal fibular fragment will be displaced and angulated lateral (valgus deformity) as shown in figures 2552 and 2563 Sometimes a lateral tibial wedge of varying size (figs 2553 2554) is sheared or twisted off from the metaphysis

Epiphyseolysis with antecurvation (figs 2555, 2556 2559, 2564) is caused by external rotation of the body with the foot fixed on the ground and at the same time plantarflexed This mechanism causes an internal rotation fracture of the tibia with a medioposterior wedge and an anterior separation of the tibial epiphysis The epiphysis with the medioposterior (fig 2556) or pure posterior wedge of the metaphysis becomes displaced posteriorly and

a torsion fracture occurs at the fibula The epiphysis may also break in one or more places (fig 2559)

Epiphyseolysis with recurvation (figs 2569, 2570) is rare Bartl, who surveyed our 232 cases of epiphyseolysis, found only four cases with recurvation These cases usually occur as a result of direct force and are of the bending and external rotation type as are the supramalleolar bending fractures (fig 2516) The tibial epiphysis becomes separated posteromedially and a wedge breaks out from the metaphysis anterolaterally The fibula breaks at the same time, its fracture line continues along the fracture line of the metaphyseal wedge In fig 2570 the big posteromedial portion of the metaphysis is fractured additionally

Diagnosis Recognition of this injury is easy in cases of gross displacement but only roentgenograms can verify cases with but slight displacement Tenderness and swelling are present in all cases Crepitation and abnormal mobility are absent Roentgenograms of both ankle joints should be made in both main planes If no significant displacement can be seen but if severe swelling and tenderness are present, roentgenograms under local anesthesia should be made in forced supination and pronation Separation of the tibial or fibular epiphysis will then, as a rule, be detected In varus fractures the roentgenograms must be studied especially carefully lest changes of the contour of the lateral malleolus be overlooked *It should be remembered that the normal lateral concavity of the lateral malleolus* (fig 2567 sketch and 2567 a) *disappears in the case of epiphyseolysis of the lateral malleolus* (figs 2561, 2562, 2567, 2571—2573)

Complications If reduction is not perfect, a lasting deformity will follow all epiphyseolyses with severe angulation Tibial and fibular epiphyseolyses with varus deformity are followed by growth disturbances *at the medial* side if varus is not corrected completely (figs 2571—2573)

Avoidance of Complications Angulation and growth disturbance can always be avoided if comparison roentgenograms of both tibiotalar joints are made especially watching for a varus deformity Angulation and especially varus deformity in which the concavity on the lateral side of the lateral malleolus has vanished, must be corrected completely

Treatment of Fresh Epiphyseolysis

Reduction can as a rule, be performed under local anesthesia Considerable force must be applied in some cases The convex side of the angulation i e, the medial side of the foot in valgus (figs 2551—2554, 2563) the lateral side in varus (figs 2560—2562, 2567, 2571, 2572), the anterior side in antecurvature (figs 2555 2556 2559 2564), and the posterior side in recurvation (fig 2569) should be placed on a well padded wooden wedge and pressure should be exerted with both hands and the whole body-weight on both fragments as shown in figure 2568 A soft click can be felt at reduction

Reduction in presence of an anterolateral bone-wedge (figs 2557, 2565, 2566) This kind of epiphyseolysis is caused by extreme dorsal flexion of a



2563 July 25 1935 2563 a November 7 1935

Fig 2563 —Pure separation of the lower tibial epiphysis supramalleolar flexion fracture of the fibula Valgus and antecurvature of 30° Lateral displacement of the tibia by a third of the diameter of the shaft and of the fibula by the full diameter of the shaft Sustained by a 17 year old waiter s apprentice who slipped on the road The fragments were reduced under local anesthesia over a padded wooden wedge (fig 2568) Split short leg cast for one week followed by a short leg walking cast for five more weeks

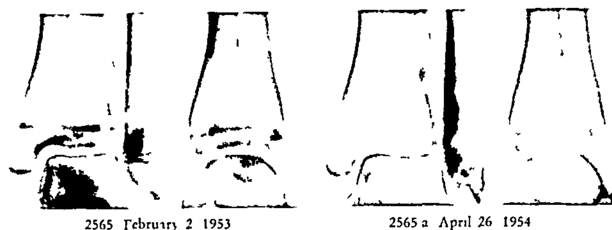
Fig 2563 a —Same case after 15 weeks Bony union in good alignment Normal shape and color of the limb Free joint motion Asymptomatic



2564 May 26 1935 2564 a July 1 1935

Fig 2564 —Lower tibial epiphyseolysis with big posteromedial torsion wedge of the metaphysis torsion fracture of the fibula The foot the epiphysis and the big torsion wedge are displaced backward for 10 mm and rotated slightly inwards Varus of 10° at the fibula (cf fig 2556) Sustained by 16 year old tailor s apprentice in a bicycle collision Reduced over a padded wooden wedge under local anesthesia (fig 2568) Split lower leg cast for one week followed by a short leg walking cast for an additional four weeks

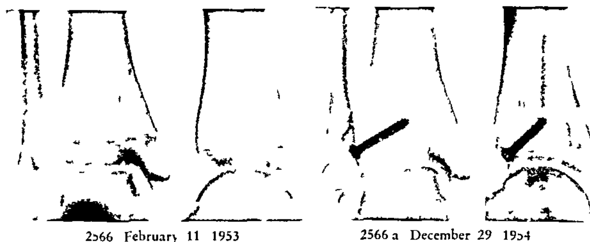
Fig 2564 a —Same case five weeks after the accident on removal of the cast Bony union in ideal position Slight bone atrophy At the follow up examination 19 years later shape color strength and motion of the foot were normal



2565 February 2 1953 2565 a April 26 1954

FIG 2565 — Fracture and anterolateral displacement of the anterolateral part of the lower tibial epiphysis Sustained by a 13 year old schoolgirl by extreme dorsiflexion and simultaneous pronation of the foot when making a bad landing after turning a somersault The same injury resulted as in figs 2531 and 2541 Under local anesthesia and with the foot in plantar flexion and supination the displaced fragment could easily be reduced by thumb pressure A split short leg cast for five days was followed by a short leg walking cast for six weeks

FIG 2565 a — Same case 15 months later Union in good position Foot of normal shape and color All joints freely movable Asymptomatic



2566 February 11 1953 2566 a December 29 1954

FIG 2566 — Fracture of the anterolateral part of the lower tibial epiphysis with the same displacement as in fig 2565 Sustained by a 16 year old schoolgirl who fell forward and sidewards when skiing The foot was extremely dorsiflexed and at the same time pronated Since this patient was admitted as late as three days after the accident and the ankle was severely swollen the fragment could no longer be reduced by manipulation When the swelling of the foot had subsided after 12 days the fracture was exposed and open reduction was achieved by pressure on the fragment There was no necessity to use a screw A split cast for one week was followed by a lower leg walking cast for another five weeks

FIG 2566 a Same case 23 months later Color shape motion and function of the foot were normal

pronated foot Plantar flexion and supination is used for reduction pressure by the thumb helps to replace the displaced fragment to its proper place (fig 2565 a)

Reduction by Increasing the Angulation If reduction cannot be achieved by flexion over the well padded wooden wedge the fragments should be



2567 April 1 1948 2567 a April 16 1954

Fig 2567—Typical bimalleolar supination fracture in a juvenile with shearing off of the medial malleolus and a medial wedge of the metaphysis The medial part of the tibial epiphysis is broken and impacted into the metaphysis Epiphyseolysis of the fibula with typical varus displacement *The normally concave lateral contour of lateral malleolus has disappeared* Sustained by a 16 year old bricklayer s apprentice who was sitting in a sidecar of a motor bicycle when it was rammed by an oncoming truck A case similar to that of the patient with the open supination fracture shown in figs 2527 2539 Reduced under narcosis by means of the Phelps Gocht apparatus which was applied in the reversed position as shown in fig 2746 Split lower leg cast for two weeks followed by a lower leg walking cast for another five weeks In this type of fracture growth will be disturbed if reduction is not accurate (see figs 2571—2573)

Fig 2567 a - Same case 6 years later The epiphyseal lines of the tibia and fibula have closed The lateral contour of the ankle has regained its concavity (see also sketch) Slight varus position of the talus Normal shape and color Asymptomatic Free joint motion



Fig 2568—Reduction of a dorsally displaced epiphysis (figs 2556 2564) under local anesthesia The foot is brought forward over a well padded wooden wedge by strong manual pressure



2569 October 19 1938 2569 a February 7, 1939

Fig 2569—Lower tibial epiphyseolysis with avulsion of a big anterolateral metaphyseal bending wedge Oblique fracture through the distal quarter of the fibula Valgus 15° recurvation 35° This injury corresponds with the supramalleolar bending fracture after closure of the epiphyseal line (see fig 2516) Sustained by a 14 year old locksmith s apprentice in a bicycle accident Since reduction over the wooden wedge failed on account of the shortening the shortening was overcome by calcaneus pin traction in the screw traction apparatus (figs 2410 2411) The angulation was then corrected over the wooden wedge A split cast for one week was followed by a lower leg walking cast for another six weeks

Fig 2569 a—Same case 16 weeks later Bony union in good position Epiphyseal line closed Normal shape color mobility and function of the foot

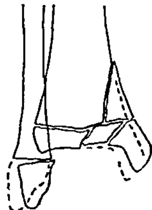


2570 December 29 1937 2570 a March 15 1938

Fig 2570—Lower tibial epiphyseolysis with big anterolateral metaphyseal torsion wedge as in fig 2569 Oblique fracture of the fibula in line with the fracture of the tibial wedge As the force continued on the metaphyseal fragment it was twisted off and stuck out under the skin Sustained by a 15 year old spinner s apprentice who was caught by the transmission belt of a spinning jenny Since manipulation in the screw traction apparatus failed to reduce the fragment reduction was performed by open operation As the fragments were stable osteosynthesis was not necessary Split long leg cast The skin badly damaged by the projecting fragment became necrotic and a small sequestrum was cast off

Fig 2570 a—Same case 11 weeks later on removal of the cast Bony union in good position Severe demineralization In 1942 the patient was killed in action during the war According to his relatives he had been asymptomatic





2567 April 1 1948 2567 a April 16 1954

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2569 October 19 1938 2569 a February 7 1939

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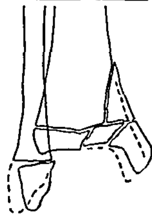


2570 December 29 1937 2570 a March 15 1938

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2567 April 1 1948 2567 a April 16 1954

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FIG 2568 - Reduction of a dorsally displaced epiphysis (figs 2556 2564) under local anesthesia The foot is brought forward over a well padded wooden wedge by strong manual pressure

infection would probably have ensued, whereas, without internal fixation, only a small superficial cortical sequestrum was cast off

Duration of Immobilization In a case of slight displacement the cast is removed four weeks after the accident In cases of severe displacement and in all supination fractures immobilization should last six weeks

Further Treatment In a case of severe displacement an Unna's paste boot may be applied for 3 to 4 weeks This is not necessary in a case of slight displacement An orthopedic brace is never necessary if reduction was complete Without further measures function of the leg will become normal within a few weeks

Delayed Treatment of Epiphyseolysis

If the injury is more than two weeks old and if periosteal callus is visible, manipulative reduction should be omitted in order to avoid growth disturbances Open reduction should be omitted lest the epiphyseal plate be damaged An exception is made only in the case of an anterolateral bone wedge (fig 2566 a) If a bad deformity ensues it can be corrected by a V shaped osteotomy (fig 2573) later on

Cause and Prevention of Growth Disturbances Following Epiphyseolysis of the Supination or Varus Type

Supination (adduction) of the foot causes avulsion of the fibular epiphysis and shearing off of the medial malleolus without (figs 2561, 2571, 2572), or with a metaphyseal fragment (figs 2562, 2567), as in supination fractures of the adults (figs 2527, 2539) The medial part of the epiphyseal plate of the tibia is compressed to a varying degree It, however, regains its old shape as does the femoral head in group I of the central dislocation of the hip (see Vol II/p 1121 and figs 1564 a—f) If the medial part of the epiphysis is comminuted and impacted into the metaphysis as in figures 2562, 2567, the bone trabeculae can no longer regain their former shape If this condition is not recognized in cases with slight displacement and, if the absence of the lateral concavity of the lateral malleolus is not noted and heeded (fig 2567 sketch), the epiphyseal cartilage of the fibula remains under constant traction and growth will be more rapid than normal A severe varus deformity of the lateral malleolus will result (fig 2572 b) As the medial side of ' epiphyseal plate of the tibia, due to the angulation of the talus, is su' to pressure on weight-bearing and to pressure by muscle pull, it can no longer grow This pressure is increased by the more rapid growth of fibula

If an epiphysis is accurately reduced so that the lateral concavity of the lateral malleolus in restored as in the sketch of figure 2567, and if the talus lies exactly horizontal both malleoli will grow normally

Shortening Following Epiphyseolysis In a case with severe displacement shortening without angulation may result from premature closure of the epiphyseal lines in spite of accurate reduction

separated by increasing the degree of angulation Reduction is then, as a rule, possible over the well padded wooden wedge in the manner described above

Reduction with the Help of Phelps Gocht's Osteoclast In varus fractures with impaction of the epiphysis (figs 2562, 2567) or metaphysis (fig 2560) reduction may prove impossible over the padded wooden wedge Phelps Gocht s osteoclast should then be used (in a reverse manner as shown in figure 2746) We used the osteoclast only twice in our 232 cases

Reduction on the Screw Traction Apparatus Existing shortening as in figure 2569 is corrected by calcaneus pin traction in the screw traction apparatus The fracture can then easily be reduced over the well padded wooden wedge *We used the screw traction apparatus in 4 of our 232 cases*

First Roentgen Check After reduction new roentgenograms are made in both main planes and compared with those of the well side Especially in varus fractures all dislocation must be corrected completely and the lateral convexity of the lower fibula must be restored Should displacement still exist reduction and roentgenograms must be repeated until perfect alignment has been achieved

Immobilization If the roentgenograms show complete reduction, a hemp cord (see p 1656) is placed on the anterior aspect of the leg and a plaster cast is applied, in cases with little displacement a short leg cast, in cases with severe displacement a long leg cast, as described on page 1724 In varus fractures one hand should be placed above the ankle, the other hand firmly pressed upon the medial malleolus and the talus to correct the varus completely

Second Roentgen Check Following application of the cast new roentgenograms are made in both main planes

Splitting the Cast If the roentgenograms show good position the cast is split immediately throughout its full length to avoid obstructing circulation When the swelling of the ankle has subsided after 2 to 3 days, the split cast is tightened by means of a bandage

Removal of the Split Bed Cast When the swelling of the ankle has subsided completely after one week the plaster cast is removed

Third Roentgen Check New roentgenograms are made after removal of the cast The lateral concavity of the lateral malleolus must be given special attention in supination fractures

Application of a Short Leg Walking Cast If the roentgenograms show good position a short leg walking cast is applied and marked as described on pages 1724—1730

Fourth Roentgen Check New roentgenograms in both main planes are made after application of the walking cast The concavity of the lateral malleolus must again be carefully considered

Osteosynthesis is never necessary because these fractures are stable after complete reduction and correct immobilization in a plaster cast If a screw is drilled through the epiphyseal plate of a growing bone growth may be disturbed In the case of figure 2566 a, growth had already stopped If screws or wires had been used to fix the fragments in the case of figure 2570 a severe

infection would probably have ensued, whereas, without internal fixation, only a small superficial cortical sequestrum was cast off

Duration of Immobilization In a case of slight displacement the cast is removed four weeks after the accident In cases of severe displacement and in all supination fractures immobilization should last six weeks

Further Treatment In a case of severe displacement an Unna's paste boot may be applied for 3 to 4 weeks This is not necessary in a case of slight displacement An orthopedic brace is never necessary if reduction was complete Without further measures function of the leg will become normal within a few weeks

Delayed Treatment of Epiphyseolysis

If the injury is more than two weeks old and if periosteal callus is visible, manipulative reduction should be omitted in order to avoid growth disturbances Open reduction should be omitted lest the epiphyseal plate be damaged An exception is made only in the case of an anterolateral bone wedge (fig 2566 a) If a bad deformity ensues it can be corrected by a V-shaped osteotomy (fig 2573) later on

Cause and Prevention of Growth Disturbances Following Epiphyseolysis of the Supination or Varus Type

Supination (adduction) of the foot causes avulsion of the fibular epiphysis and shearing-off of the medial malleolus without (figs 2561, 2571, 2572), or with a metaphyseal fragment (figs 2562, 2567), as in supination fractures of the adults (figs 2527, 2539) The medial part of the epiphyseal plate of the tibia is compressed to a varying degree It, however, regains its old shape as does the femoral head in group I of the central dislocation of the hip (see Vol II/p 1121 and figs 1564 a—f) If the medial part of the epiphysis is comminuted and impacted into the metaphysis as in figures 2562, 2567, the bone trabeculae can no longer regain their former shape If this condition is not recognized in cases with slight displacement and if the absence of the lateral concavity of the lateral malleolus is not noted and heeded (fig 2567, sketch), the epiphyseal cartilage of the fibula remains under constant traction and growth will be more rapid than normal A severe varus deformity of the lateral malleolus will result (fig 2572 b) As the medial side of the epiphyseal plate of the tibia, due to the angulation of the talus, is subjected to pressure on weight-bearing and to pressure by muscle pull it can thus no longer grow This pressure is increased by the more rapid growth of the fibula

If an epiphysis is accurately reduced so that the lateral concavity of the lateral malleolus in restored as in the sketch of figure 2567, and if the talus lies exactly horizontal, both malleoli will grow normally

Shortening Following Epiphyseolysis In a case with severe displacement shortening without angulation may result from premature closure of the epiphyseal lines in spite of accurate reduction

Treatment of Growth Disturbance Following Epiphyseolysis

If, due to inaccurate reduction, varus fractures are followed by typical disturbed growth and angulation as shown in figures 2571—2573, progression of the deformity can, according to Hohmann [1]), be stopped by means of a weigth-bearing splint. Hohmann presented roentgenograms of a 6 year old boy whose deformity was corrected by wearing a weight-bearing splint for two years. In severe deformity a V-osteotomy of the tibia is performed which must not reach the epiphyseal zone and an



2571 March 8 1951 2571 a April 10 1952

FIG 2571 —The medial malleolus has been sheared off from the epiphysis the lateral malleolus has been separated in the epiphyseal line Diastasis between talus and medial malleolus a sign that the talus was severely displaced medially The fibular epiphysis is slightly displaced medially *The typical concavity at the lateral malleolus has disappeared* In this position a cast was applied without reduction

FIG 2571 a —Check roentgenogram 13 months later Retarded growth medially varus of 20° *The concavity at the lateral malleolus is missing* (From Hohmann [1])



2572 2572 a 2572 b

FIG 2572 —Supination fracture of both malleoli with severe displacement

FIG 2572 a —Same case Without reduction a cast has been applied in 15° supination

FIG 2572 b —Same case two years later 30° supination of talus 25° supination of the lateral malleolus *Instead of the normal lateral malleolus there is a convexity* (From Giuliani [2])

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1 Hohmann G Zur Korrektur frischer und veralteter Falle von Verletzung der distalen Tibiaepiphyse Arch orthop u Unfallchirurg *45* 395—399 1952

2 Giuliani Spatzustande nach traumatischen mechanischen Schadigungen der Epiphyse am distalen Tibiaende Arch orthop u Unfallchirurg *45* 386—394 1952

oblique frontal osteotomy of the fibula A valgus position is then created (fig 2573 a) This operation is much simpler and a more gentle procedure than the wedge osteotomy shown in figures 2576—2581 In children under 14 years of age the talus should be brought into slight valgus Thus, the fibular epiphyseal cartilage is subjected to pressure and growth will be retarded The pressure on the tibial epiphyseal plate, however, is diminished and growth will be stimulated If a varus deformity recurs, osteotomy of both bones should be repeated and stapling (epiphyseodesis) of the fibula according to Blount[1] should be performed, in addition To avoid recurrence



2573 July 6 1953 — 2573 a July 8 1953 — 2573 b October 4 1953

Fig 2573—Growth disturbance following lower tibial epiphyseolysis of the supination type 30° varus of the tibia and 10° varus of the fibula 18 months after the injury Sustained by a 13 year old boy who while riding a bicycle was hit by a car

Fig 2573 a—Same case Roentgenogram following V osteotomy of the tibia and oblique frontal osteotomy of the fibula Varus of 5°

Fig 2573 b—Same case 15 months later Bony union of the osteotomy sites Epiphyseal lines closed The leg appears straight in spite of the 15° varus at the talocrural joint because of the 15° valgus of the fibula External shape color mobility and functional capacity of the leg are normal

in severe cases Hohmann's weight-bearing splint should be used Blount suggested stapling of the upper tibial epiphysis of the well side in order to correct shortening of the injured leg

Questions We Should Ask Ourselves in Order to Avoid Failures When Treating Epiphyseolysis of the Lower Tibia and Fibula

1 Have I obtained roentgenograms of both ankle joints in both main planes?

2 Have I in dubious cases, obtained anteroposterior roentgenograms of both ankle joints under local anesthesia in forced supination and pronation?

[1] Blount W Fractures in Children Baltimore Williams and Wilkins 1954

3 Have I paid special attention to the lateral concavity of the lateral malleolus in varus fractures (sketch of fig 2567)?
4 *Have I placed the convex side of the fracture on a well* padded wooden wedge and corrected the deformity under local anesthesia by strong manual pressure (fig 2568)?
5 Have I reduced an anterolateral metaphyseal wedge by thumb pressure the foot being plantarflexed and supinated (figs 2565, 2565 a)?
6 Have I placed the concave side of the fracture on the well padded wooden wedge and increased the angulation to separate the fragments if reduction with the convex side on the wedge, was impossible? Have I than corrected the angulation after placing the convex side over the wedge again?
7 Have I, in impacted varus fractures (figs 2562, 2567), corrected the angulation with Phelps-Gocht s osteoclast if reduction proved impossible over a well padded wooden wedge?
8 Have I corrected severe shortening in the screw traction apparatus (figs 2410, 2411), prior to correcting the angulation over the well padded wooden wedge?
9 Have I obtained roentgenograms in both main planes after reduction, and compared them with the well side?
10 Have I, especially in varus fractures, confirmed that the concavity at the lateral side of the lateral malleolus has been restored (sketch of fig 2567)?
11 Have I repeated reduction if the roentgenograms, especially in varus fractures, did show that reduction was not complete? Have I repeated reduction and roentgen check until the position has become satisfactory?
12 Have I, after application of the cast, obtained new roentgenograms in both main planes?
13 Have I immediately, i e, before the patient has left the plaster room split the cast through its full length and thickness to avoid circulatory embarrassements?
14 Have I, when the swelling has begun to subside after 2 to 3 days, tightened the cast with bandages?
15 Have I removed the split temporary bed cast after one week?
16 Have I obtained new roentgenograms in both main planes after removal of the temporary bed cast?
17 Have I applied a short leg walking cast if the roentgenograms show good position?
18 Have I again obtained roentgenograms in both main planes following application of the lower leg walking cast, and have I looked for the concavity of the lateral malleolus especially in varus fractures?
19 Have I, in all cases, refrained from osteosynthesis since drilling through the epiphyseal plate may cause growth disturbances?
20 Have I removed the walking cast after four weeks in cases with slight dis placement, and after six weeks in cases with severe displacement and in all supination fractures?

21. Have I obtained new roentgenograms in both main planes after removal of the cast?
22. Have I refrained from prescribing a weight bearing splint after removal of the walking cast?
23. Have I refrained from attempts at manipulative reduction in cases older than two weeks?
24. Have I prescribed a weight-bearing splint (according to Hohmann) for one or two years in cases of slight growth disturbance?
25. Have I, in cases with severe varus, performed a V-osteotomy of the tibia and an oblique frontal osteotomy of the fibula?
26. Have I avoided the epiphyseal plate when performing a V-osteotomy?
27. Have I stapled the epiphysis of the fibula (according to Blount) if a varus deformity has recurred?
28. Have I, in shortening, stapled the upper epiphyseal plate of the well tibia in time?

Results of Treatment in 232 Cases of Epiphyseolysis at the Distal End of the Tibia and Fibula

Bartl (see p. 1844) summoned 100 patients out of a number of 232 patients who had been treated in our hospital in the 26 years from 1928 until 1953 for follow up examination, 54 appeared for re-examination. These patients appeared by virtue of their injury to be especially prone to growth disturbances.

Among the 54 re examined cases there were 5 cases of pure epiphyseolysis, 23 with fracture of the metaphysis, 9 cases with fracture of the epiphysis and 17 with fractures of both the metaphysis and epiphysis. The period between the end of treatment and re-examination ranged from 22 years to six months, in most cases 2 to 8 years. None of the re-examined patients complained of significant pain. Some felt the change of weather. The mobility of the ankle joint and subtalar joint was free in all cases.

Slight angulation was visible in the roentgenograms of four cases, namely, varus in three cases and valgus in one case. This angulation was less than 10° in all cases, it was not discernible clinically and it caused no trouble. In all four cases the deformity had already been visible in the roentgenograms following removal of the cast. No case with good alignment upon removal of the cast developed a deformity later. In only one case was there a 2 cm shortening of the lower leg. It occurred in a 14 year old girl who at the age of 12, suffered an epiphyseolysis with a large medial metaphyseal wedge. Reduction of the fragments was complete. The roentgenograms following removal of the cast showed perfect alignment. The girl was asymptomatic at the re examination and the best in gymnastics in her class. At re examination the roentgenogram showed premature closure of the epiphyseal line.

A thorough study of all roentgenograms yielded three more cases with angulation, namely, valgus of less than 10°. The total number of cases with deformities is therefore eight. The distribution of the cases with deformity is as follows

Three cases with varus of less than 10°

Among them there are two cases of epiphyseolysis with fracture of the metaphysis In one case the medial part was impacted into supination like a green-stick fracture (fig 2560) The third case was an open epiphyseolysis in an unskilled worker who fell 7 M from a scaffolding He hit a pole with his ankle The primary displacement was 15° valgus, 15° antecurvature and 2 cm lateral displacement

Four cases with valgus of less than 10°

Among these cases there were three cases of epiphyseolysis with fracture of the metaphysis, and one case with fracture of the epiphysis In the latter, the lateral part of the epiphysis was compressed into pronation

One case had a 2 cm shortening of the lower leg

This followed epiphyseolysis with fracture of the metaphysis

With the exception of the case with shortening we have concluded from our study of the roentgenograms that these slight deformities could be avoided by still more accurate reduction When carrying out reduction in a case of epiphyseolysis of the supination type special attention must be paid to a perfect position of the fibular epiphysis since even the slightest displacement of the lateral malleolus may cause a varus deformity at the tibiotalar joint

All deformities noted on follow-up examination had already been present at the end of the treatment, they had caused no complaints and were not visible from outside They were detectable only by roentgen examination and had an angulation of less than 10°

These statistics prove that deformities and growth disturbances following epiphyseolysis of the lower tibia and fibula can be avoided in all cases, if complete reduction is performed within the first few days and if, especially in varus fractures, the concavity of the lateral contour of the lateral malleolus (fig 2567) is restored

While studying the literature I learned that all cases developing growth disturbances of the supination type had not been accurately reduced and that the lateral concavity of the lateral malleolus had not been restored after reduction

106 OLD AND MALUNITED FRACTURES OF THE TIBIA AND FIBULA

Cause Angulation rotation and shortening are caused by poor reduction or by insufficient or too short immobilization Concerning the duration of immobilization one must know that two or three times the normal period of time will be necessary for consolidation, i e, 20 to 30 instead of 10 to 12 weeks, in the case of primary excessive traction Shortening and rotation occur only during the first few weeks angulation may occur later, when the cast has been removed before consolidation of the bones

Varus as a rule, causes more complaints than valgus of the same degree Varus, together with recurvation and internal rotation, causes the most complaints Shortening following fractures of the lower leg is of no great

importance as it seldom exceeds 2 cm Figures 2574 a and 2575 show that angulation of as little as 10° can be seen clinically Such angulation can easily be overlooked in a small size roentgenogram if it is not carefully read I witnessed law-suits where surgeon and radiologist declared the fracture to have united very well since no lateral displacement had occurred, while all witnesses testified that the patient had walked well before the accident but limped afterwards The roentgenograms were similar to those of figure 2574 a Lateral displacement however, without angulation is often declared a poor position although as a rule it causes neither functional nor cosmetic disturbances

Possible Ill-Effects Following Malposition Angulation and rotatory displacement may lead to pain in the whole limb and later on to arthrotic changes of the ankle and subtalar joints, less frequently of the knee and hip joints

Avoidance of these Complications In order to avoid pain and arthrotic changes we must aim at avoiding malposition or at correcting it early when it is present

Conservative Treatment of Malposition Following Closed Fractures of the Tibia and Fibula

In the first few months angulation can be corrected in most cases by bending with both hands The central fragment should be held with one hand, the distal fragment should be pushed by the other hand, which is as far distal to the site of fracture as possible I describe this in detail because in hundreds of roentgenograms, especially of the forearm, I have noticed that this simple rule had not been followed In many a case the surgeon failed at manipulation because the fixing hand was placed too far distally instead of holding the bone proximal to the fracture

If the fragments have united to a certain degree they can be bent straight by Phelps-Gocht s osteoclast (fig 2746) In cases with delayed callus formation this is possible until six months after the accident or even later If the roentgenograms then show good position a long leg cast is applied for, as a rule, six weeks New roentgenograms in both planes are made after application of the cast

Conservative Treatment of Malposition Following Open Fractures of the Tibia and Fibula

Malposition following open fractures of the lower leg should be corrected particularly carefully Lateral displacement in fresh open fractures may be corrected only within the first few hours Later manipulation often leads to severe infection (see Vol I/p 160, and pp 1781, 1782) Angulation especially recurvation (angulation with an angle concave anteriorly) which often results in a split cast, can be corrected in the first few weeks by removing the cast (if there is no fever) placing the leg on a well bandaged lower leg splint, and lowering the fore foot traction (see p 1796) Four to six weeks after the injury recurvation can easily be corrected by placing a rubber roll under the site of



2574 August 2 1929 2574 a October 22 1930



2574 b January 30 1931 2574 c March 16 1937

fracture Thus, the angulation is corrected by the weight of the foot (see p 1796) In varus or valgus the patient should lie on his side and the rubber roll should be placed under the lateral or medial aspect of the fracture site If, in a case of infection, all inflammation has subsided completely Phelps Gocht s osteoclast may be used for bending the fracture two to three months after the



2575 January 28, 1931 2575 a March 16 1937

FIG 2574—*Open* shearing fracture of the mid shafts of both tibia and fibula sustained by a 15 year old hairdresser's apprentice who was run over by a motorcycle Wound excision Reduction with screw traction Lower leg plaster cast which was split immediately Calcaneus pin traction of 5 kg At present we treat this type of fracture with medullary wires (figs 2458 to 2463)

FIG 2574 a—Same case 14 months later Bony union without lateral displacement but with valgus and antecurvature of 10° each Compare with fig 2575

FIG 2574 b—Roentgenogram after oblique osteotomy of fibula and excision of a wedge with a distal base from the tibia Wire loop Valgus abolished Antecurvature of 10° persistent At present we perform a V osteotomy at the level of the fracture as shown in figs 2577 a and 2579 a

FIG 2574 c—Same case 6 years later Bony union No lateral angulation antecurvature of 10° Asymptomatic Compare with fig 2575 a

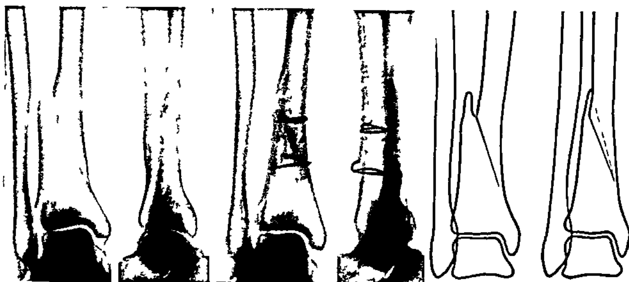
FIG 2575—Photographs to fig 2574 a *Open* fracture of left tibia and fibula Valgus and antecurvature of 10°

FIG 2575 a—Same case six years after operative correction of malposition (see figs 2574 b c)

injury We did this in hundreds of gunshot fractures during the war *The screw traction apparatus must not be used for correction of shortening and lateral displacement in old cases of open fractures of the tibia and fibula*

Operative Treatment of Malposition Following Fractures of the Tibia and Fibula

Skin Preparation Satisfactory condition of the skin at the site of osteotomy is a prerequisite for good healing Scars that are firmly adherent to bone must be excised Small skin defects can be closed by undermining the skin or sliding skin grafts The new defect is covered by a dermatome graft In some cases the skin edges can be approximated with ease after excision of bony prominences (fig 2579) After the subcutaneous sutures have been applied, the margins of



2576 November 27 1936 2576 a September 17, 1937 2576 b

Fig 2576 —Ten months old torsion fracture of tibia with varus of 15° in a 40 year old female The angulation resulted from too short immobilization of only 5 weeks at another hospital

Fig 2576 a —Same case 10 months after oblique osteotomy and excision of a bone wedge with a supero lateral base Two wire loops and full leg cast for 8 weeks

Fig 2576 b —Left side Tracing of fig 2576 with scissor cut in a medio distal direction Right side Overlapping of the cut surfaces until the fragments are in line In this way the size of the bone wedge to be removed is determined



2577 August 21 1950 2577 a 2577 b December 1 1950

Fig 2577 —Five year old torsion fracture of tibia in a 30 year old female Varus and antecurvature of 15° The angulation resulted from poor reduction and too short immobilization of only six weeks

Fig 2577 a —Same case Varus abolished after oblique osteotomy of fibula and V osteotomy of tibia Long leg cast for ten weeks

Fig 2577 b —Same case three and a half months later Bony union 5° recurvation



2578 June 8 1948 — 2578 a June 11 1948 — 2578 b November 6 1948

Fig. 2578.—Three year old gunshot fracture of tibia in a 21 year old man. Varus of 25°.

Fig. 2578 a.—Same case. Good alignment after oblique osteotomy of fibula and V osteotomy of tibia proximal to the sclerosed fracture site. The point of the "V" showed upwards. Full leg cast for ten weeks.

Fig. 2578 b.—Same case five months later. Bony union, valgus of 8°.



2579 March 7 1950 — 2579 a — 2579 b November 22 1950

Fig. 2579.—Four year old open infected fracture of the tibia and fibula in a 29 year old man. Valgus of 20°, recurvation of 10°.

Fig. 2579 a.—Same case after double osteotomy of the fibula and V osteotomy of the tibia distal to the fracture site. The "V" pointed downwards. Loose wire loop. Long leg cast for 14 weeks.

Fig. 2579 b.—Same case 8½ months later. Bony union, varus of 5°.

the skin must be in contact Pedicle skin grafting from the other leg or thigh may be necessary in large skin defects If the donor defect is at once covered by a dermatome graft, the wound on the well side will have healed by the time the pedicle is severed This direct pedicle flap requires only three weeks as opposed to the migrating double pedicle flap that requires some months

Determination of Type and Site of Osteotomy Formerly we used the wedge osteotomy At present we usually perform a V-osteotomy which is a simpler as well as a more accurate procedure The osteotomy should not be performed through the sclerosed fracture ends, particularly in cases with previous infection



2580 September 3 1952 2580 a 2580 b December 2 1954

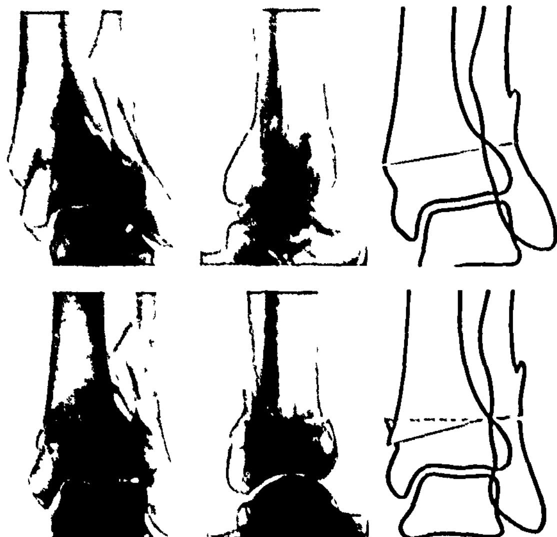
FIG 2580—Eight month old intra articular impaction fracture of the distal end of the tibia in a 28 year old man Varus of 15° recurvation of 20° The lateral contour of the fibula is convex instead of concave

FIG 2580 a—Same case after oblique osteotomy of the fibula and V osteotomy of the tibia The V points downwards Long leg cast for ten weeks

FIG 2580 b Same case after 2¼ years Good alignment

Before the wedge osteotomy the roentgen image is traced and cut out In fractures of the shaft the tracing paper is incised obliquely at the convex side as shown in figure 2576 a, in juxta-articular fractures the tracing paper is incised transversely to the concave margin as in figure 2581 a The distal part is angulated until it is in line with the proximal one The overlapping portion indicates the width of the bone wedge to be removed (figs 2576 b, 2581 c) The base of the wedge can be measured in millimeters The fibula should be cut in an oblique frontal plane not horizontally as shown in the sketch In angulations in the sagittal plane (antecurvation or recurvation) the fibula is cut in an oblique sagittal plane

Time of Operation Malposition following a closed fracture can be operated at any time if the general condition is good Patients who had open fractures may be operated on only when the skin is normal After excision of scars or pedicle skin grafting the osteotomy must be delayed for at least six months until the flap has healed well and has become well nourished If operation is done too early, the skin edges may become necrotic which may lead to infection of the bone



Top: 2581 October 1 1936 Top: 2581 a
Bottom: 2581 b December 2 1936 Bottom: 2581 c

FIG. 2581 Seven month old supramalleolar bending fracture of right tibia and fibula sustained by a 33 year old woman who fell from a tree. Valgus of 15° at the tibia of 20° at the fibula. Treated elsewhere with lower leg cast for four weeks. Forceful massage and energetic passive movements.

FIG. 2581 a Tracing of roentgenogram with a medial and a lateral cut.

FIG. 2581 b Same case eight weeks after operation. From the tibia a transverse wedge was excised whose base measured 7 millimeters medially and 3 millimeters anteriorly. The fibula was cut in an oblique frontal plane. Long leg cast for eight weeks. Bony union. Good alignment.

At present we treat such angulation with a V osteotomy as shown in fig. 2580

FIG. 2581 c For comparison with fig. 2581 a. Overlapping of the cut surfaces so that the fragments come in line. The same was done with the tracing of the lateral roentgenogram to determine the size of the bone wedge to be removed.

Anesthesia The operation is performed under general or spinal anesthesia and in a bloodless field.

Osteotomy The fibula is exposed through a lateral longitudinal incision and cut with a chisel or the blade of the circular saw in an oblique either frontal or sagittal plane. Then the tibia is exposed subperiosteally through a long straight or slightly curved incision. In the V osteotomy one hole should be drilled through the cortex at the point of the "V", and two holes each should be drilled at the sides of the "V" so that splintering of the bone be avoided when

the skin must be in contact Pedicle skin grafting from the other leg or thigh may be necessary in large skin defects If the donor defect is at once covered by a dermatome graft, the wound on the well side will have healed by the time the pedicle is severed This direct pedicle flap requires only three weeks as opposed to the migrating double pedicle flap that requires some months

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2580 September 3 1952 2580 a 2580 b December 2 1954

FIG 2580—Eight month old intra articular impaction fracture of the distal end of the tibia in a 28 year old man Varus of 15° recurvation of 20° The lateral contour of the fibula is convex instead of concave

FIG 2580 a—Same case after oblique osteotomy of the fibula and V osteotomy of the tibia *The V points downwards Long leg cast for ten weeks*

FIG 2580 b Same case after $2^1/_4$ years Good alignment

Before the wedge osteotomy the roentgen image is traced and cut out In fractures of the shaft the tracing paper is incised obliquely at the convex side as shown in figure 2576 a, in juxta-articular fractures the tracing paper is incised transversely to the concave margin as in figure 2581 a The distal part is angulated until it is in line with the proximal one The overlapping portion indicates the width of the bone wedge to be removed (figs 2576 b 2581 c) The base of the wedge can be measured in millimeters The fibula should be cut in an oblique frontal plane, not horizontally as shown in the sketch In angulations in the sagittal plane (antecurvation or recurvation) the fibula is cut in an oblique sagittal plane

Time of Operation Malposition following a closed fracture can be operated at any time if the general condition is good Patients who had open fractures may be operated on only when the skin is normal After excision of scars or pedicle skin grafting the osteotomy must be delayed for at least six months until the flap has healed well and has become well nourished If operation is done too early, the skin edges may become necrotic which may lead to infection of the bone

5 Have I, after osseous union, corrected angulation and lateral displacement by a wedge shaped (figs 2574 b, 2576, 2581) or still better by a V-osteotomy (figs 2577—2580)?
6 Have I excised scarred skin and, if necessary, covered the defect with a pedicle flap before the osteotomy?
7 Have I closed the skin without tension after excision of the scars?
8 Have I, after excision of the scars and especially after pedicle flap coverage, delayed the osteotomy for at least six months in order to avoid necrosis of the skin and infection?
9 Have I performed the osteotomy proximal or distal to the sclerosed fracture site, especially in cases which were infected?
10 Have I placed the V-osteotomy so that the point of the narrow and hard part can be inserted into the wider part of the bone (figs 2577—2589)?
11 Have I corrected lateral displacement after the osteotomy (fig 2579)?
12 Have I applied a loose wire loop if there was a tendency towards lateral displacement (fig 2579 a)?
13 Have I performed the osteotomy in an intermediate plane between both main planes if there was angulation in both main planes?
14 Have I obtained roentgenograms in both main planes after the osteotomy, after application of the cast, before and after application of the long leg walking cast, every 2 or 3 weeks while in plaster, after removal of the walking cast and before discharge?

107 DELAYED CALLUS FORMATION IN FRACTURES OF THE TIBIA AND FIBULA

To achieve an appropriate shortening is the most important aim of fracture treatment as every fracture is followed by devitalization and absorption of the fracture stumps, of from 0 5 to 3 mm, due to severance of vessels and subsequent impairment of circulation An opportunity must, therefore, be given for the fracture stumps to approach each other The aim of treating a fracture of the lower leg bones should be to produce a shortening of from 1 to 5 mm and under no circumstances a lengthening This statement may cause some surprise, because up till now the aim has always been to eliminate any shortening The amount of shortening to strive for is usually 5 mm or less

Lengthening of a bone by separation of the fragments (dislocatio ad longitudinem cum elongatione aut distractione) is the most dangerous of all displacements since it may cause all the severe complications stated in Vol I/pp 26, 27 (see also figs 2490, 2491, 2518)

I have agreed with Ender[1] and Zrubecky not to speak of delayed callus formation until consolidation of the tibia and fibula takes more than 20 weeks in closed fractures or more than 30 weeks in open fractures

Origin At present delayed callus formation most frequently results from continuous skeletal traction with excessive traction weights It is also a

[1] Ender Krotschek, and Jahna Hefte zur Unfallheilkunde 1956
Zrubecky Hefte zur Unfallheilkunde 1956

it is cut by the chisel The bone may also be cut with an electric or a pneumatic circular saw When chiselling the bone, both sides of the wedge should be dealt with simultaneously and not first one and then the other The planes in the V should be placed in such a way that the point of the thinner and harder part of the shaft be placed into the wider and softer part of bone This applies especially for juxta-articular osteotomy So, the pointed part of bone is directed proximally in an osteotomy at the upper end of the tibia (fig 2578 a), and distally in an osteotomy at the lower end of the tibia (fig 2580 a) If the fracture site is sclerosed the point is formed from the hard part of bone In severe lateral displacement, after osteotomy the distal fragment can be brought into line with the proximal one by leverage and traction with a single pronged *bone hook (fig 2579 b)*

If *angulation* exists in both main planes as in figure 2577 the V-osteotomy is done neither in the sagittal nor in the frontal plane but in an intermediate plane (fig 2577 a)

If there is a tendency towards lateral displacement a wire loop is applied loosely The wounds are closed with periosteal and skin sutures If necessary a rubber drain is inserted for one day

First Roentgen Check Before closure of the skin roentgenograms are made in both planes

Immobilization If the roentgenograms show good position a long leg plaster cast is applied as shown on page 1724 The cast is split throughout its full length

Second Roentgen Check After application of the cast new roentgenograms are taken from both sides

Application of the Long Leg Walking Cast If the wound has healed after two weeks a full leg walking cast is applied as described on pages 1724 to 1737 This cast is not split Existing angulation can easily be corrected

Third Roentgen Check After application of the long walking cast new roentgenograms are taken in both planes These are repeated every 2—3 weeks

Period of Immobilization The long leg walking cast is removed ten weeks after the operation Then, the firmness of the bone is tested clinically Roentgenograms in both planes must be taken in all cases In absence of osseous *union a new long leg walking cast must be applied for at least another six weeks*

Questions We Should Ask Ourselves in Order to Avoid Failures When Treating Old and Malunited Fractures of the Tibia and Fibula

1 Have I placed one of my hands proximal to the fracture site when bending straight an angulated fracture?
2 Have I, in open fractures of the tibia and fibula avoided correcting lateral displacement or shortening by forceful measures, e g, screw-traction, after the first day since severe infection might result (see Vol I/p 162 pp 1781, 1792, 1798)?
3 Have I gently corrected angulation following open fracture of the tibia and fibula by placing the leg on a rubber roll within the first few months?
4 Have I used Phelps Gocht s osteoclast to correct angulation if this could not be achieved manually?

108 NON-UNION OF THE TIBIA AND FIBULA

Of all cases of non union those of the tibia and fibula are the most common at present We speak of non union if the fracture ends are rounded off, pointed or thickened, and if there is a definite bony occlusive operculum of the medullary cavity One cannot speak of pseudarthrosis until after 6 months have passed

Origin At present the most frequent cause of non-union is skeletal traction with weights of more than 3 Kg (Vol I/figs 330—338, figs 2518, 2586—2605, M N [1]/figs 322—971) In open fracture or weakly muscled patients traction of 2 kilograms may be excessive thus causing delayed union and non union Sometimes excessive traction for only a few days leads to this disastrous complication I saw hundreds of roentgenograms like figure 2518 during World War II Many of those cases ended in amputation Moreover, non-union of the tibia is often seen following operative treatment with or without subsequent infection Osteosynthesis — with exception of medullary wires, loose wire suture or loose wire loop — prevents the fracture stumps from approaching each other after they have undergone devitalization and absorption (see pp 1746—1764)

The frequently cited interposition of muscles and tendons plays a minor role It may occur in cases where a gap between the fracture stumps has been created by excessive continuous traction as in M N /figs 305 306

During World War I non-union often followed gunshot fractures because of complete removal of all bone splinters This was rarely seen during the World War II In peace-time defect-pseudarthrosis as shown in figs 2608, 2609 a is rare since bone splinters are no longer removed Such big gaps are never caused by the accident alone

Too short immobilization combined with early massage and passive movements is seen only rarely nowadays I have never seen a systemic disease to be the cause of non-union of the lower leg bones

Blood circulation is comparatively poor in the distal third of the lower leg This explains the high incidence of non-unions and also ulcers in that region

Non-union of the tibia was an exception before the time of osteosynthesis and continuous skeletal traction Its high incidence at present, is shown by Kaspar s report (see p 1700) Excessive continuous traction or osteosynthesis were present in all his cases The results of our follow-up investigations show that non-union can, as a rule, be avoided Of our 1130 closed and 505 open fractures of the tibia and fibula only two of the closed and two of the open cases developed non union They resulted from excessive traction (figs 2418 to 2425) and osteosynthesis They could have been avoided by the early use of an onlay graft I have written in detail about the causes of non-union in Vol I/pp 239—250 and M N /pp 90—144

Diagnosis Non-union is as a rule, easily detectable by abnormal mobility and thickening at the fracture site, and by impaired function Roentgenograms must be made in both main planes since the gap of non-

[1] Medullary Nailing of Kuntscher by Lorenz Bohler translated by Hans Tretter Baltimore Williams & Wilkins 1948

frequent sequela of osteosynthesis In both instances the fragments of the tibia cannot approach each other after resorption of the devitalized fracture stumps The fibula, as a rule, consolidates regardless and then acts as a strut to hold the tibial fragments apart

Ender found the following periods of consolidation in our 1130 closed cases

Average period of consolidation	75 5 days
Period of consolidation	
in 40 cases with distraction	201 3 days
in 17 cases of osteosynthesis	106 days

Zrubecky found the following periods of consolidation in our 506 fresh open fractures of the tibia and fibula

Average period of consolidation	128 3 days
Period of consolidation	
in 42 cases with distraction	346 4 days
in 39 cases of osteosynthesis	194 3 days
	(except cases of medullary nailing)

A further cause of delayed callus formation is infection with formation of sequestra (fig 2505) or the presence of Lane s plates (fig 2477) or other metal foreign bodies which prevent the fracture stumps from approaching each other In cases with multiple fractures consolidation is frequently delayed in one fracture site General causes, such as age and so on, are rare

Prevention of Delayed Callus Formation Osteosynthesis should be performed as rarely as possible Continuous skeletal traction should never exceed 3 kg but should often be less Lateral diastasis should be corrected in time Check roentgenograms should be taken on the second day in order to detect a diastasis soon enough (fig 2423)

Treatment If no callus is visible and the fracture is still mobile in closed cases of 12 to 16 weeks duration, osteotomy of the fibula should be performed to allow for approximation of the tibial fragments If no callus is visible at the tibia after 16 weeks an onlay bone graft should be performed (see p 1871)

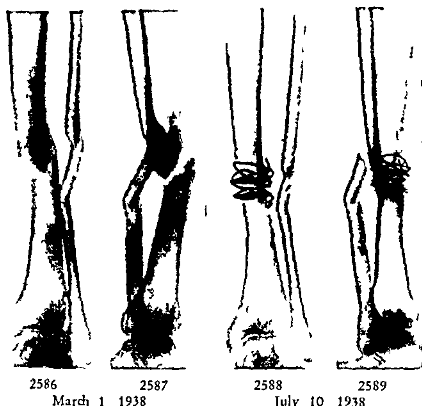
In the presence of sequestra or foreign bodies bony union frequently follows their removal (figs 2477—2480, 2506—2508) and no further measures are necessary Angulation may be corrected at the same operation (figs 2505 to 2508) The operation is followed by a long leg walking cast for 10 weeks The necessary roentgenograms should be made as decribed on page 1866 Oblique osteotomy of the fibula allows the tibial fragments to approach each other Callus formation and bony union (figs 2510—2512) will ensue within weeks or months Consolidation is stimulated by weight-bearing on the well aligned fragments A second osteotomy of the fibula is necessary only n exceptional cases

We have given up Beck s drilling as the heat produced may lead to necrosis and infection

4 In four cases of extensive scarring we have observed union to take place following pedicle skin grafting alone

5 Non union *with draining sinuses* are best treated by *Greifensteiner's* compression osteosynthesis (figs 2606, 2607)

We have given up Beck's drilling on account of the danger of infection Kirschner s comminution of the bone stumps and the method of Brandes of sawing the ends of the bones in the longitudinal direction as well as freshening the bone ends with subsequent bone suture have been abandoned by us In a case as shown in figures 2586—2589, osteotomy of the fibula, correction of



2586 2587 2588 2589
March 1 1938 July 10 1938

Figs 2586, 2587 —Established non union of tibia which is visible only in the lateral and not in the anteroposterior view one year after the accident Sustained by a 28 year old lumberman who was hit by a tree Treated elsewhere by wound excision and calcaneus wire traction of 8 kg for 3 weeks followed by a walking cast for 8 weeks As the fracture was still mobile 5 months after the accident an osteotomy of the fibula was performed The patient began walking with the aid of crutches without plaster immobilization

Figs 2588 2589 —Same case after oblique osteotomy of the fibula and oblique freshening of the tibial fragments in order to open the medullary cavities The fragments were sutured by three perforating wire loops Firm osseous union in good position was achieved three months after the operation

the angulation of the tibia, and the use of an onlay bone-graft will as a rule, lead to union

Phemister s Onlay Grafting If we think of the big bone transplantations we used to perform for non-union the simple onlay-graft appears almost a miracle Its astonishing effect however, can be easily explained Each case of non union is a problem of blood circulation Also in closed fractures distraction by either continuous traction or osteosynthesis leads to vessel spasm

union may not be visible in the anteroposterior picture as in figures 2586 and 2590 Additional oblique pictures are necessary in some cases

Treatment The administration of *chemical agents, hormones, vitamins* and different injections of ossifying agents or blood is useless as has been stated in Vol I/pp 244—250 and the case history on page 248

Of the different methods of operative treatment we use the following

1 *Phemister's onlay grafting* with simultaneous osteotomy of the fibula (figs 2604, 2605) is a relatively gentle and very reliable method of operation in non-union with the fragments in contact Osteotomy of the fibula alone is an uncertain procedure



Figs 2582 2583—Non union of tibia with draining sinus following a *closed* fracture of the tibia and fibula in a 20 year old student who had suffered a motorbicycle accident one year previously He had been operated on with Lane s plates Severe infection followed Recurvation of 35⁰ resulted and pronounced drop foot position No signs of a sequestrum On account of the severe suppuration a windowed walking cast was applied on October 27 1934 The sinu closed four months later Achillotenotomy on April 12 1935 Correction of angulation of tibia by Phelps Gocht s apparatus and refracture of fibula Long leg walking cast for five months Osseous union resulted

Figs 2584 2585—Same case ten months after correction of the angulation Bony union in good position

2 Transplantation of large bone grafts is only used in non-union with big gaps between the bone stumps (defect pseudarthrosis)

3 In big defects of the tibia and in extensive scars we transplant the fibula into the tibia (Hahn s operation fig 2509) If the fibula is not yet strong enough (fig 2609 a) an orthopedic splint is given at first

Preparation of Skin In contradistinction to the operation for malposition, Phemister's operation can be performed even in the presence of small scars adherent to the tibia, if the skin is normal lateral or dorsal to the tibia so that the incision can be placed there Large scars must be excised and if necessary a pedicle graft should be applied as described on page 1864

Preparation of the Bone In the presence of discharging sinuses, sequestra and foreign bodies must be removed The operation should be delayed until



2596 2597 2598 2599 2600 2601
March 16 1937 March 21 1937 January 27, 1938

FIGS 2596 2597—Non union of tibia following a closed fracture of the tibia and fibula Treated elsewhere by calcaneus wire traction weighted with 9 Kg for 4 weeks Osteotomy of the fibula 8 months after the accident yielded no success

FIGS 2598, 2599—Same case following performance of a 10 cm long sliding bone graft and re osteotomy of the fibula Osseous union was achieved three months after the bone grafting operation At present we treat such cases with an onlay graft

FIGS 2600 2601—Firm osseous union ten months after bone grafting

six months after closure of the sinuses The blood sedimentation rate should also be determined If no infection had occurred and if the surface over the fracture site is smooth no further preparation is necessary

Anesthesia and Bloodless Field If skin and bone are satisfactory, the operation is performed under spinal or general anesthesia in a bloodless field

Osteotomy of the Fibula In all operations for non union of the tibia the fibula should be osteotomized by use of the chisel or circular saw at the old fracture site or at the level of the fracture of the tibia

Operation on the Tibia The *skin incision* is placed either lateral to the anterior or slightly dorsal to the medial crest of the tibia, namely, where the surface of the fracture site is relatively straight and where the skin (after open

and, thus, to impaired circulation (see Vol I/pp 26, 27) In severe open fractures circulation is impaired because many vessels have been severed The circulatory conditions become still worse from additional distraction and operation The fact that union may be achieved in cases where a pedicle graft has been done for the *extensive scars adherent to bone*, proves that union depends on improvement of the circulation Whereas, formerly we used to expose subperiostally both fracture ends and excise the sclerosed bone ends, open up the medullary cavities widely and fasten a big bone graft with wire



Figs 2590 2591 —Two year old non union of the tibia The gap of non union is visible only in the lateral view not in the A P view Varus of 15° The medullary cavities of both fragments are closed up by thick sclerosed opercula Sustained by excessive traction (8 Kg through 4 weeks) too short immobilization of only 6 weeks and premature massage Treated elsewhere

Figs 2592 2593 – Same case after open osteotomy of the fibula and percutaneous drilling of the tibia The drill holes can be well seen Varus corrected At present we treat such cases with an onlay graft

Figs 2594 2595 – Same case 2 years after the drilling Sclerosis of fracture ends has become less dense the shape of the medullary cavities has improved The small defects at the anterior aspect of the tibia have filled by bone

or screws, we now expose only one side of the bone without significantly disturbing *the circulatory conditions* The stimulus of a relatively small graft placed between bone and periosteum avoiding foreign bodies will lead to osseous union in a comparatively short time The effect of the onlay graft is best demonstrated in those cases which have been operated on previously one or several times by other methods (figs 2602—2605)

Concerning the *time of operation* the same applies as in operation for correction of malposition (see p 1864)

broad and should not include the anterior margin of the tibia We observed a fracture of the tibia in a case where we had excised a 13 millimeters broad graft Bone bank grafts may also be used or the graft may be taken from the patient s well tibia The graft is positioned in such a way that it overlaps both bone ends equally and that both ends come to lie under sound periosteum In case exuberant callus had been chiseled off it should now be laid over the graft The periosteum and the skin are sutured over this The donor area of



2605 September 8 1952 — 2605 a September 12 1952 — 2605 b April 25 1955

Fig 2605 —Four year old non union at upper third of tibia following an open fracture of the lower leg Sustained by a 28 year old engineer in a motor bicycle accident Treated elsewhere with calcaneus wire traction of 3 to 9 Kg Three operations for non union followed First a compression osteosynthesis three months later open medullary nailing with freshening of the bone ends and 15 months after the accident bone grafting and wire sutures the graft being taken from the well tibia The graft did not take on account of infection

Fig 2605 a —Same case After excision of the scars had been performed seven months previously the fibula was osteotomized and the angulation of the lower leg was corrected Projecting callus was excised laterally an 8 by 90 mm bone graft taken from the well tibia and laid on Split full length bed cast for 3 weeks followed by a full length walking cast for 3 months On removal of the cast i e 110 days after the operation the fracture was clinically firm

Fig 2605 b —Same case 2½ years later Osseous union with varus of 5° This angulation occurred because the cast was removed too early The lateral side of the former fracture is reinforced by the well united tibial graft

the graft is drained for 24 hours In non-union near the upper or lower end of the tibia one end of the graft is put into a preformed groove in the tibia Suture of the periosteum and the skin A sterile cord is then placed over the front of the limb, a compression bandage is put on and a full length plaster cast which is split immediately is applied for 2 to 3 weeks This cast is followed by a full length walking cast which is removed 12 weeks after the operation A big advantage of this operation is that the firmness existing at the time of operation is not disturbed Moreover, the bone is reinforced, especially in lateral defects as shown in figure 2605

fractures) is more movable One should never try to approach the tibia through the fibular incision, since one would have to dissect through the entire width of the leg From a medial or anterior incision the tibia lies directly under the skin Vessels and nerves in the interosseous space can also be damaged when using the fibular approach and arrest of hemorrhage is difficult



2602 November 3 1952 — 2603 November 7 1952 — 2604 November 10 1953

FIG 2602 —Two year old non union of right tibia following a closed fracture of the lower leg of a 30 year old farmer Previous treatment by compression osteosynthesis was not successful

FIG 2603 —Same case after re operation The fibula was osteotomized angulation of the lower leg was corrected exuberant callus at the lateral side of the tibia was chiseled off and an 8 by 80 mm bone graft taken from the proximal third of the tibia was laid on The donor area is well seen Long leg temporary bed cast for 3 weeks followed by a long leg walking cast for 3 months On removal of the cast 112 days after operation the bones were firm clinically

FIG 2604 —Same case one year later Firm osseous union The former fracture site is reinforced laterally by the well united graft Figures 2602—2605 b are taken from Ender s paper [1]

Exposure of the Bone Ends In an anterior incision only the lateral side of the tibia is exposed subperiostally, in a medial incision only the posterior side For laying on the graft smoothly projecting callus as in figures 2602—2605 is chiseled off with or without its periosteum

Excision and Application of the Graft A longitudinal incision is made down to the bone over the proximal third of the tibia A 8 by 80 millimeter graft is excised by means of the double circular saw The graft should not be too

[1] Ender J Erfahrungen mit Anlegespan bei der Behandlung von Pseudarthrosen und von Bruchen mit verzogerter Heilung Der Chirurg 25 409—411 1954

its distal end comes to lie proximally, the gap of non-union is bridged by normal bone

In the case of severe bone atrophy a 10 to 12 mm by 100 mm piece of bone should be excised Half of its length should be taken from the proximal fragment, the other half from the distal fragment A graft of equal size is taken from the well tibia for bridging the non-union The piece of bone from the injured tibia is put into the donor bed of the well tibia After insertion of a drain, periosteum and skin are sutured on both sides The drains are



2608 January 21 1937 — 2609 March 2 1938

Fig 2608—Non union with big defect (defect pseudarthrosis) of tibia following an open fracture of the lower leg seven years previously The patient at the time 20 years of age had had two big skin wounds but no loss of bone When infection occurred several bone splinters were removed elsewhere in several operations The wound was irrigated with different chemical agents and packed A dimpled hard scar resulted which was adherent to the bone Varus of 30° Fibula twice the normal thickness Such defects of tibia never result from the accident but only from operative removal of bone splinters

Fig 2609—Same case one year after excision of the fibular head and implantation of the fibular shaft into the head of the tibia Bony union in good position Can walk without the aid of a cane

removed after 24 hours A long leg cast, which is split immediately, is applied on both sides Three weeks later a long leg walking cast is applied on the injured side for a further 12 weeks

Transplantation of the Fibula According to Hahn in Big Defects of the Tibia In the case of big defects in the tibia the skin is usually dimpled and severely scarred Bone-grafting is thus rendered impossible In these cases the

Check roentgenograms should be done as outlined on page 1866

End Results Ender published the results of our 10 cases of non union and 15 cases of delayed callus formation which were operated upon by onlay grafting in the two years from 1951 to 1953 The number of operations has meanwhile risen to 73 There has been no case of infection Osseous union was achieved in all cases, the average period necessary for consolidation was 112 days



2606 June 13 1946 — 2606 a June 14 1946 — 2607 August 22 1947

FIG 2606 — Two year old infected non union of right tibia and fibula with sequestra following a gunshot fracture

FIG 2606 a — Same case after sequestrectomy and compression osteosynthesis with two wires according to Greifensteiner The wires were removed after 6 weeks Full leg cast for 3 months

FIG 2607 — Same case 14 months later Bony union of tibia in good position Sinus closed

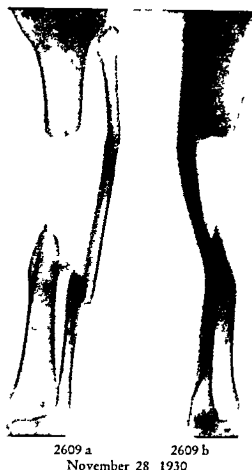
Bone Grafting in Small Defects of Tibia The skin must be freely *movable* on the underlying surface and it must show satisfactory circulation Scars adherent to the bone must be excised Pedicle grafting may be necessary The operation should then be delayed for six months (see p 1864) If the skin is *freely movable, the fibula is osteotomized through a lateral incision* The tibia is exposed through a medial incision If the calcium content of the injured tibia is satisfactory, the graft is taken from the injured side, otherwise it is taken from the well side The graft may also be taken from the bone bank If the graft is taken from the injured side its size should be 10 to 12 mm by 150 mm and it should be excised with the double circular saw in such a manner that depending on the site of non-union, one third of the length of the graft is cut from the *proximal* fragment and two thirds from the *distal*, or vice versa The medial crest of the tibia should not be used If the graft is then reversed so that its proximal end comes to lie distally and

The operation is done under general anesthesia in a bloodless field At first the fibula is obliquely osteotomized but segment of several cm should not be excised as has often been recommended Extensive excision of the fibula weakens the weight bearing capacity of the leg During the last war I have seen many cases of re-fracture of the tibia as consequence of too extensive fibular excision The length of the excised part of bone should never exceed 2 cm Then the site of non union is exposed and sequestra are removed A longitudinal notch is cut into both bone ends to insure against subsequent rotation The bone ends are freshened transversely Then the skin over the proximal fragment is drawn proximally and the skin over the distal fragment is drawn distally Then a 1 8—2 mm stainless wire is drilled through each fragment in a frontal plane 2 cm distant of the fracture cleft Both wires are fixed to the stirrup shown in figures 2369 and tightened as described on pages 1685—1687 If the roentgenograms show good position pressure is applied on the wound and the tourniquet removed After removal of the tampon 5 to 10 minutes later, there is, as a rule, only little hemorrhage Bleeding vessels are clamped but not ligated in order to avoid thread fistulas A drain is inserted at the tibia and one at the fibula and the skin is closed If the taut wires press on the skin it should be incised Long leg cast which is split immediately and fenestrated After check roentgenograms the leg is positioned on an oblique splint When absorption has started about 10 days later, the screw is given another turn This is repeated every other day until the middle of the fourth week Six weeks after the operation the cast and the wires are removed After clinical examination of the firmness and after new roentgenograms a long leg walking cast is applied for another three months By that time the fracture has, as a rule, consolidated (figs 2606, 2607)

Questions We Should Ask Ourselves in Order to Avoid Failures in Treating Non-union of the Tibia and Fibula

1 Have I removed sequestra and foreign bodies in non-union with persistent draining sinus?
2 Have I, after closure of the sinus, excised scars adherent to the bone and closed the resulting defects by sliding or pedicle skin grafts?
3 Have I, after infected non-union, examined the blood sedimentation rate before a bone operation?
4 Have I delayed the bone operation as late as six months after closure of the sinus?
5 Have I, in transverse non-union of the tibia, performed only the simple onlay grafting according to Phemister?
6 Have I osteotomized the fibula before operating on the tibia?
7 Have I incised the skin over the tibia either anteriorly or medially, namely where the skin is well movable and the bone surface is even?
8 Have I avoided using a fibular incision for exposing the tibia (danger of damage to vessels and nerves)?
9 Have I exposed only one of the three surfaces of the tibia?
10 Have I excised projecting callus for better apposition of the onlay graft?

head of the fibula is excised and the shaft of the fibula is implanted into a sufficiently large groove at the upper end of the tibia If the defect pseud arthrosis is of long standing, the fibula has usually become thick and strong enough to carry the body weight (fig 2609) At this operation the angulation of the tibia is also corrected



2609 a 2609 b
November 28 1930

Fig 2609 a b—Big defect of tibia following *open* double fracture of the tibia and fibula Although but a small wound was present the intermediate tibial fragment was removed elsewhere and the wound was packed Two years after the accident there was a large dimpled scar with a central ulcer so that bone grafting was impossible The roentgenograms before the removal of the intermediate fragment were similar to those of figs 2437 2438 Such cases should be provided with an orthopedic splint until the fibula has become thick enough for an operation according to Hahn (figs 2608 2609)

Compression Osteosynthesis in Non-Union of the Tibia with Draining Sinus For cases where the sinuses remain open in spite of sequestrectomy Greifensteiner,[1] one of my former assistants, inaugurated the compression osteosynthesis He used this method in 150 cases The advantage is that this operation can be performed before the sinus closes and that no foreign body is buried in the gap of non union

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1 Greifensteiner Beitrag zur Pseudarthrosenbehandlung Med Klinik 1947 42 Eine Methode zur Behandlung von noch eiternden Pseudarthrosen und Schlottergelenken Ztschr f Orth 77, 1947

Bandage for Transportation to the Main Clearing Station or the Field or Base Hospital In contradistinction to gunshot fractures of the femur it is relatively easy to apply an immobilizing bandage for gunshot fractures of the lower leg The simplest method is to place the leg in a sheet-iron boot (gutter splint) with a supporting cross-piece A double Cramer wire splint may be used whereas a single Cramer wire splint is too weak A transportation extension splint may be used if available

Questions We Should Ask Ourselves in Order to Avoid Failures in Treating Gunshot Fractures of the Tibia and Fibula at the First Aid Post

They are the same as in gunshot wounds of the hip joint (see Vol II/p 1145)

Treatment at the Main Clearing Station or at the Field and Base Hospital

Application of heat, treatment of shock and *cleaning the wound with the scalpel* are carried out as in gunshot fractures of the femur (see Vol II/p 1483)

Suture of severed nerves does not come into practical consideration

Bone splinters must not be removed since this leads to defect pseudarthrosis (figs 2609 a, b)

Amputation must be performed immediately if soft tissue and bone are severely comminuted and if the dorsalis pedis and posterior tibial pulses are absent but can be felt well on the uninjured side Severe comminution of bone is in itself no indication for amputation The amputation wound must not be closed by suture

Avoidance of Wound Infection and Elimination of Pain By Uninterrupted Immobilization The best way to avoid wound infection and permanently to relieve pain after thorough excision of the wound is to provide complete uninterrupted immobilization of the entire leg up to the hip or with inclusion of the pelvis Penicillin or other indicated antibiotics should be administered at the same time

Bandage for Transportation to the Special Army Hospital After the wounds have been cleaned with the scalpel, the patient with gunshot fractures of the lower leg should at once be evacuated to a special hospital for gunshot fractures and gunshot injuries of the joints He should remain in that special hospital *without interruption* until he is completely healed The best transportation bandage is the *padded* and fenestrated plaster cast extending from the tip of the toes up to costal arch

Fenestration of the Plaster Cast Fenestration is performed in the same way as in gunshot fractures of the femur (see Vol II/p 1486)

All wounded men with fresh plaster casts must be kept warm after application of the cast and during transportation

Splints If there is no possibility of applying a plaster cast, the leg is placed in a sheet metal boot (gutter splint) with a supporting cross piece (see p 1703) A double Cramer wire may also be used

11 Have I, when using an autoplastic graft, taken the bone from the medial side of the tibia and have I left the anterior crest in order to avoid fracture of the donor tibia?
12 Have I taken a bone graft of 8 by 80 mm?
13 Have I positioned the onlay graft in such a way that it overlies both bone ends equally, and that it comes to lie under normal periosteum?
14 Have I added to the graft pieces of callus previously chiseled off?
15 Have I, in non-union near the upper or lower end of the tibia, cut a groove into the end of the tibia to insert the graft?
16 Have I inserted a drain at the donor site?
17 Have I, after suture of periosteum and skin, applied a long leg temporary bed cast and split it immediately?
18 Have I, if the wound has healed without complication applied a long leg walking cast three weeks after operation for another nine weeks or longer if necessary?
19 Have I performed a sliding bone graft in the case of a small tibial defect (figs 2596—2601)?
20 Have I inserted the fibula into the tibia according to Hahn (figs 2608 2609) in the case of a large tibial defect and of severely scarred skin?
21 Have I performed a compression osteosynthesis in non-unions with draining sinuses which have not closed in spite of sequestrotomy (figs 2606, 2607)?
22 Have I prescribed an orthopedic splint if the fibula was still too slender for Hahn's operation (figs 2609 a, b)?

109 GUNSHOT FRACTURES OF THE TIBIA AND FIBULA

Frequency Among Jimeno Vidal's cases, gunshot fractures of the lower leg are in first place (29 7%), among my cases they rank in third place (21 8%) see Vol I/pages 199—205

Site of Fracture Among Jimeno Vidal's[1] cases there were 286 gunshot fractures of the tibia and fibula, 309 fractures of the tibia alone, 75 fractures of the fibula alone, and 107 incomplete fractures

The *displacement of the fragments* is, as a rule, the same as in closed fractures

Nerve Injuries The peroneal nerve is often injured in fractures of the upper third Vidal observed seven cases

Vessel Injuries Gangrene usually results from severance of both main arteries This, however, is rare Injury to only one of the two main arteries causes no great disturbance

TREATMENT OF GUNSHOT FRACTURES OF THE TIBIA AND FIBULA

Treatment at the First Aid Post

Treatment of shock, arrest of hemorrhage, wound dressing anesthesia warming up the patient, tetanus prophylaxis, and injections of penicillin are provided as in gunshot wounds of the hip joint (see Vol II/pp 1143, 1144)

[1] Jimeno Vidal Arch orth u Unfallchir *41* 685 1941

the splint in order to keep the blanket well off the wound and to keep the blanket clean There was an attached wooden board to prop the sound foot against it Army beds were used with straw sacks so firmly packed with excelsior that the Braun splints lay exactly level and never sank down All was prepared so as to be able to admit ten patients with gunshot fractures per hour When the wounds had healed sufficiently a walking cast was applied

Treatment of Aseptic Gunshot Fractures of the Tibia and Fibula

Treatment of shock and retention of the immobilizing transportation bandage are carried out as in gunshot wounds of the hip joint (see Vol II/p 1149)

If the roentgenograms show good position of the fragments the transportation bandage may be retained for three weeks A long leg walking cast is then applied and remains until 10 weeks after the injury

In the case of severe displacement, extension, as described on pages 1704 to 1724, is applied three weeks after the injury This will correct angulation Shortening and lateral displacement must not be corrected in a screw traction apparatus since this may cause severe infection (see Vol I/p 160, p 1781 and figs 2505—2508)

If angulation has been corrected, a long leg walking cast is applied as described on pages 1724—1737

Treatment of Infected Gunshot Fractures of the Tibia and Fibula

Most gunshot fractures of the tibia and fibula are infected Of Jimeno Vidal s cases 78% were infected, among my cases 88% Wound infection is comparatively slight I had no fatal outcome among my cases and only one patient required amputation on account of simultaneous infection in the knee joint

The most important things in the treatment of every infected gunshot fracture of the lower leg are that there be adequate drainage and uninterrupted immobilization of the entire leg, and that there be adequate and rational administration of antibiotics Exercises of all the joints not included in the cast and in fact of the entire body must not be negelcted

Roentgenogram After treatment of shock (see Vol II/p 1149) roentgenograms in both planes are obtained in the transportation bandage

Retention of the Immobilizing Bandage The strain and the jarring of transportation cause many patients with gunshot fractures of the lower leg to have elevated temperatures when they are admitted to the special Army Hospitals If the immobilizing cast fits well, if the wounds appear to have been well treated and show no evidence of developing infection, and if position and alignment of the fragments is good, the transportation cast is retained for some days until the patient's general condition has improved Otherwise the cast is removed

Exposure of abscess cavities was necessary in only 10% of my personal cases, especially in relatively small projectile wounds and in lodging wounds

Marking the bandages is carried out as in gunshot wounds of the hip joint (see Vol II/p 1148)

Questions We Should Ask Ourselves in Order to Avoid Failures in Treating Gunshot Fractures of the Tibia and Fibula at the Field and Base Hospital

1 Have I noted the form and color of the leg while treating shock with internal and external application of heat?
2 Have I palpated the dorsalis pedis and posterior tibial pulses of both feet?
3 Have I in packed wounds arrested hemorrhage by ligation?
4 Have I obtained roentgenograms in both planes?
5 Have I amputated, if the pulses in the foot were absent, if the toes were pale and without sensation, and if there was no capillary return on pressure of the toenails?
6 Have I refrained from closing the amputation wound by suture?
7 Have I refrained from excising small projectile wounds?
8 Have I refrained from suturing small projectile wounds?
9 Have I excised the wounds while they were fresh?
10 Have I excised only the gross devitalized parts and removed only visible foreign bodies in wounds of long standing?
11 Have I given penicillin locally and systemically?
12 Have I applied a padded plaster hip spica for transportation?
13 Have I fenestrated the transportation cast?
14 Have I marked the transportation cast?
15 Have the patients with plaster casts been kept warm?

DEFINITIVE TREATMENT OF GUNSHOT FRACTURES OF THE TIBIA AND FIBULA AT THE SPECIAL HOSPITAL

In my Special Army Hospital for gunshot fractures and gunshot wounds of the joints at Bozen[1] during the years 1916—1918 after shock was treated roentgenograms in the transportation bandage were obtained from both sides and then the bandage removed Sheet iron boots (gutter splints) and Cramer wire splints were frequent plaster casts were rare The leg was then cautiously cleaned and put on a Braun splint Under local anesthesia a Schmerz clamp was applied or a pin was driven through the calcaneus At the lower end of the bed there was a pulley carrier to which the splint was firmly attached by a scissors shaped spreader (Vol I/fig 364 n, fig 2378 e) Later on the leg was placed on a lower leg splint (fig 2484) Longitudinal traction was exerted with a weight of 3 kg (fig 2378 e) At the site of the wound a small window was cut in the bandage of the splint to allow for evacuation of pus into a basin underneath (fig 2484) The wounds were treated without a dressing The forefoot was suspended with a skin adhesive strip in order to avoid drop foot position and pressure on the heel Angulation in the sagittal plane, especially recurvation, can at the same time be corrected Two stirrups were attached to

1 Bohler L Über die Einheitsbehandlung der Unterschenkelbruche Munchen med Wchnschr *64* 68—71

the splint in order to keep the blanket well off the wound and to keep the blanket clean There was an attached wooden board to prop the sound foot against it Army beds were used with straw sacks so firmly packed with excelsior that the Braun splints lay exactly level and never sank down All was prepared so as to be able to admit ten patients with gunshot fractures per hour When the wounds had healed sufficiently a walking cast was applied

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Exposure of abscess cavities was necessary in only 10% of my personal cases, especially in relatively small projectile wounds and in lodging wounds

The incisions should be placed at the medial or lateral and not at the posterior aspect Abscesses should, as a rule, not be exposed through the calf Drains should not be guided through the interosseous space and should not be guided transversely through the lower leg since this may cause arosion hemorrhage After exposure of the infected foci the temperature usually subsides to normal within 4—8 days

In cases of *gas phlegmon* or *malignant epifascial edema* in addition to the deep incisions, numerous 5 to 6 cm long incisions are made at 2 to 3 cm distances These incisions should extend into healthy tissue proximally and distally for a few centimeters If all the edematous, with pus infiltrated tissues have been exposed, one generally succeeds in stopping this dangerous infection Antibiotics are of great help

In *genuine gas gangrene* which usually starts in the thick calf muscles amputation was necessary in former times Its signs are described with the gunshot fractures of the femur (Vol II/p 1491) At present the leg can often be preserved by antibiotics

Application of a Long Leg Plaster Cast After exposure of the infected foci a pin or wire is driven through the calcaneus and a long leg plaster cast is applied as described on pages 1724, 1725 The rules given on pages 1793—1796 should be observed No attempt should be made to correct shortening or lateral displacement by manipulation or in the screw traction apparatus since this might lead to severe infection (see Vol I/p 160, p 1781) Angulation however, and slight rotation are corrected before application of the cast The cast must extend up to the hip joint (fig 2485 a) A lower leg cast (fig 2485) is not sufficient immobilization Longitudinal traction in the cast is weighted with 3 Kg in slight displacement and with 6 Kg in marked displacement

Treatment with Double Pin or Double Wire Transfixion Plaster Cast Jimeno Vidal used this method with excellent results in 102 cases For reasons given on page 1747 I have stopped using this method in 1934 The procedure is described on pp 1747—1749 In infected cases screw traction must be avoided

Further Treatment of Infected Gunshot Fractures of the Tibia and Fibula

Check Roentgenograms New roentgenograms should be made in both planes one or two days later In case of still existing shortening the traction weight is increased Angulation and lateral displacement cannot be corrected in the temporary bed cast

Treatment of Infected Gunshot Fractures of the Tibia and Fibula by Traction Since angulation cannot be corrected in the full leg cast, we use traction in patients if they have been without elevated temperature for at least two weeks Treatment is carried out as described on page 1796

Wound treatment without dressing is carried out as described on page 1796 Free bone splinters at the anterior side of the tibia must not be removed since this might lead to defect pseudarthrosis If the splinters are left in place only a thin superficial lamella 1—2 mm thick, will be cast

off as in Vol II/fig 2166 k I emphasize this since so many guests in my hospital used to ask why the bone splinters lying exposed were not removed

Adequate windows are cut in the cast As long as there is marked discharge of pus the wounds are treated without dressings Later on, especially when the patient is up, the wounds are covered by a dressing The dressing should be undisturbed as long as possible, i e, one to three weeks The dressing should be accurately cut so that it fills the window completely in order to avoid window edema In many cases it is more expedient to leave the plaster cast closed

Septic secondary hemorrhage occurs rarely in gunshot fractures of the tibia and fibula if immobilization is uninterrupted and if no drains are guided through the interosseous space or transversely through the calf In the case of secondary hemorrhage the wound should not be occluded with a pressure dressing but the spurting vessel must be ligated in order to avoid recurrence of the hemorrhage

Avoidance and Treatment of Tubular Abscesses Tubular abscesses only occur if infected foci have not been sufficiently exposed and if immobilization has not been permanent In my personal 131 cases I did not observe a single case of infection spreading beyond the ankle or knee joint Should tubular abscesses occur they must be incised wide enough to provide for drainage

Treatment of Amputation Stumps As soon as the acute signs of inflammation have subsided, traction is applied by means of a stockinet tube which is fastened to the skin by a skin adhesive solution (e g , Mastix) This prevents the skin of the stump from retraction The stockinet tube is drawn together by a string 6 to 7 cm distal to the end of the stump so that the margins of the skin are pulled together If the stockinet tube is kept apart by a ring instead of tying it together it cannot act on the skin margins When the wound has become clean *secondary* suture may be performed

Treatment in the Long Leg Walking Cast In small wounds a long leg walking cast may be applied from the toes up to the mid-thigh in the fourth week, no matter whether the patient has been previously treated by continuous traction or in a plaster cast In large wounds one should wait until they have become smaller In patients with double pin or double wire transfixion casts the pins should be removed after six weeks at the earliest, if no inflammation occurs at the pin sites After removal of the pins a long leg walking cast is applied The sites of the wounds must be windowed in some cases When the patient becomes ambulant the windows must be accurately filled with dressings to avoid window edema

Check roentgenograms should be made every 2 to 3 weeks, so that displacement, especially angulation, can be corrected in time

Exercises In aseptic and in infected cases the toes must be actively exercised through their full range of movement from the first day on In case of paralysis the patient should use slings to dorsiflex his toes Patients with plaster casts should have a piece of foamrubber or cellulose under the toes This holds them in slight dorsiflexion which can be overcome by active flexion In contradistinction to patients with femoral fractures, patients with fractures of the lower leg should not be encouraged to do quadriceps exercises

since this might displace the fragments If the patients stay in bed a long time the sound leg should be exercised on the mountain climbing apparatus (Vol I/figs 21, 22) Arm exercises are added which, at the same time, act as breathing exercises

Duration of Immobilization Some aseptic gunshot fractures with comminution consolidate as early as after eight weeks On the average it takes four months until the bones can bear weight without being immobilized in plaster In partial loss of bone splinters the cast may have to remain for even 6 to 8 months until the defect has been bridged

Check Roentgenograms After removal of the cast the firmness is tested and roentgenograms are made in both planes

Further Treatment Following removal of the cast an Unna's paste bandage is applied from the web of the toes up to the knee and an elastic bandage round the knee in order to avoid swelling of the lower leg The knee becomes swollen in some cases The effusion usually subsides after 1 to 2 weeks if vigorous therapy is avoided

Energetic massage and forceful passive movements must be avoided since this even after several months, may lead to inflammation and to irritation of the neighboring joints

Exercises must not cause pain (see Vol I/p 45)

Sequestrectomy is performed as in infected fractures of the lower leg (see pp 1796, 1797)

Non-union after gunshot fractures of the tibia and fibula may follow operative removal of bone splinters or application of too heavy traction (fig 2518) Even big defects of bone may be bridged if permanent immobilization is kept up for long enough a period Delayed callus formation at the tibia can be speeded by osteotomy of the fibula

Treatment of non-union is performed as after closed fractures of the tibia and fibula (see pp 1871—1879 and figs 2582—2609 a)

Treatment of Foot Drop Foot drop due to poor treatment is corrected by closed oblique Achillotenotomy followed by a lower leg walking cast for four weeks

Treatment of Flexion Contracture of the Basal Joint of the Great Toe The best treatment is to remove the proximal two thirds of the basal phalanx

Treatment of Hammer Toes The extensor aspect of the proximal interphalangeal joint is incised longitudinally through skin and extensor tendon down to the bone and into the joint The collateral ligaments are cut and the trochlea of the basal phalanx is excised with the rongeur The skin is closed by sutures The extensor tendon is included in the skin suture

Questions We Should Ask Ourselves in Order to Avoid Failures in the Treatment of Gunshot Fractures of the Tibia and Fibula

The points are the same as in infected fractures of the lower leg (see p 1797) Regarding the traction bandage the questions given on pages 1715 and 1718 should be considered and regarding the long leg plaster cast those on page 1735

Further Development of Gunshot Fractures of the Tibia and Fibula and Results

Mortality Of Jimeno Vidal's 777 cases, 12 (1 5%) died 3 from gas gangrene, 2 from tetanus, 7 from sepsis Of Arguelles' 322 cases, 7 (2 2%) died

Amputation Jimeno Vidal carried out amputation in 5 cases, of which 4 were fatal Arguelles performed 10 amputations (3 1%)

Functional Results Jimeno Vidal achieved his best results by means of the double pin transfixion plaster cast Of 102 cases 82% healed without shortening or angulation Of the remaining 245 gunshot fractures of both lower leg bones 63 5% healed in good position Angulation exceeded 10° only exceptionally and never exceeded 12° Shortening of more than 1 cm occurred in 6 patients it was in no case more than 2 cm There were no cases of foot drop or significant flexion contracture of the knee

My own results are given in Vol I/p 202

110 RUPTURE OF THE ACHILLES TENDON

Etiology In 80% of our cases rupture of the Achilles tendon resulted from indirect violence, e g, in high-jumping or broad-jumping, at football, or at tennis, and also in ordinary running or in slipping or lately at skiing (due to a new type of binding) In 20% of our cases the rupture resulted from direct violence, if the patient was hit upon the heel We have in no case observed simultaneous rupture of both Achilles tendons, but there were four patients among our 105 personal cases who ruptured both of their Achilles tendons at different times Tennis more often leads to sprains and tears of the calf muscles than to rupture of the Achilles tendon

The *histological examination*, performed in 28 cases, showed degenerative signs of the tendon in the 21 cases resulting from indirect force The remaining 7 cases showed regenerates with granulation tissue and round cell infiltration Thus, a normal tendon does not rupture unless by direct violence

Distribution of Age, Sex, and Side of the Body Rupture of the Achilles tendon is observed most frequently between 30 and 50 years of age The average age in our cases is 39 years Our youngest patient was 22, our oldest 58 There were 70% men and 30% women, whereas rupture of the rectus tendon was only observed in men (see p 1513) Distribution of the right and left side of the body was about equal

Frequency The number of these ruptures has markedly increased since 1949 In the 23 years from December 1925 to December 1948 we observed 25 cases of rupture of the Achilles tendon among 379,634 patients, whereas in the 7 years from January 1949 to December 1955 we observed 80 cases among 259,902 patients In the year 1955 we observed a total of 20 cases We have not found out the reason for this increase in incidence The figures were collected by Schonbauer (see footnote on p 1892)

Pathology The tendon as a rule, ruptures at its point of smallest diameter, i e, 3 to 5 cm proximal to its insertion at the tuber calcanei The ruptured ends are, as a rule, frayed out (fig 2609 a) In all our 105 cases the Achilles

tendon was severed completely whereas the adjoining tendon of the plantaris muscle remained uninjured (fig 2609 e) Some authors, taking it for a part of the Achilles tendon, believed in the existence of incomplete tears of this tendon

Complications Without operative treatment the ruptured tendon heals with lengthening The calf muscles become weak, walking is impeded, walking on tiptoe is no longer possible Delayed suture of the tendon is followed by some weakness of the calf muscles but there remains no significant disturbance

Avoidance of Complications The above mentioned complications are avoided by suture of the tendon





2609 c 2609 d

FIG 2609 c—*Three months old rupture of the Achilles tendon* Marked gap at the site of rupture The left calf is weaker than the right

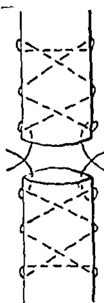
FIG 2609 d—Nineteen month old rupture of the Achilles tendon Dorsiflexion at talocrural joint markedly increased (Figs 2609 c and d are taken from Schonbauer s paper See footnote on p 1892)

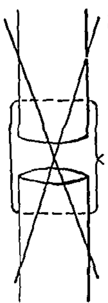
Diagnosis If a patient tells of a sudden severe pain like a blow or an *electric shock, which he felt or sometimes* even heard in the region of the Achilles tendon when he engaged in sports or was at work, if he complains of pain in that region, if he limps and cannot tiptoe, one should think of a rupture of that tendon Within the first few hours after the accident, i e before swelling sets in one can usually see and palpate a gap above the heel Later on that area becomes swollen and discolored from hematoma The gap in the tendon again becomes visible and palpable (fig 2609 c) when the swelling has disapeared Though the patient can no longer walk on tiptoe, active plantar flexion is possible to 13% of the normal power by the following muscles Musc flexor digit long, flexor hallucis long, peronaeus long peronaeus brevis tibialis post plantaris 87% of the power of plantar flexion is supplied by the Achilles tendon and its muscles The power of plantar flexion is examined in the supine patient who is told to

plantarflex his feet as strongly as possible The examining doctor tries to passively dorsiflex the foot This will not be possible with one hand on the well side but will be possible with one finger on the injured side In old cases not only passive but also active dorsiflexion is markedly increased In soft tissue roentgenograms the gap in the Achilles tendon may be visible

In spite of the history and signs of this tendon rupture being obvious this injury is often overlooked because active plantarflexion is still present to some extent Of our cases 40% had not been diagnosed before they were admitted to the hospital Those patients had been treated under different diagnoses such as sprains, muscle or ligamentous tears, phlebitis, bursitis







2609 e 2609 f 2609 g

FIG 2609 e —Picture of the Achilles tendon frayed out for 3 cm The uninjured thin tendon of the plantaris muscle is visible close to the ruptured Achilles tendon

FIG 2609 f —Suture of the Achilles tendon performed with a straight needle

FIG 2609 g —Single circular suture which easily cuts through

Treatment Only suture of the ruptured tendon promises success

Time of Operation As the frayed out ends of the tendon can hardly be caught by the suture, we generally operate as late as three weeks after the accident when the tendon ends have become more solid In the meantime the patient may walk about without treatment

Tendon Suture in Fresh Cases We operate under general or spinal anesthesia and in a bloodless field The patient lies in prone position The 10 to 15 cm long skin incision is placed just medial to the Achilles tendon A midline incision may be followed by a sensitive scar The incision should not be placed laterally in order to avoid disturbance of the skin branches of the sural nerve The peritendineum should not be severed at the ventral side where the nutrient vessels enter the tendon

The tips of the frayed out tendon ends are cut off Two straight needles are threaded with strong silk sutures Two to three centimeters proximal to the central stump one needle is put transversely through the tendon in a frontal plane The suture is placed in the manner shown in figure 2609 f, i e, it crosses twice in each stump The tendon stumps are approximated by plantarflexion of the talocrural joint and the four ends of the sutures are tied Thus the knots are buried in the tendon tissue Fine longitudinal sutures are added all around the tendon The last few years we have placed the tendon of the plantaris muscle, which can be spread out to a 2 cm broad sheet, around the site of suture and fixed it with sutures Thus, the surface of the tendon becomes smooth and will not adhere to the skin One single suture as shown in figure 2609 g may cut through and the stumps may separate After suture of the tendon the wound is packed and the tourniquet removed There is, as a rule, no bleeding after 5 minutes tamponade After a few fine subcutaneous sutures the skin is closed

In two cases of curved lateral incisions the skin nerve had accidentally been included in the suture Severe pain developed and ceased only after removal of the stitches and careful re-suture of the skin

Tendon Suture in Old Cases The tendon is exposed as in fresh cases The tendon stumps are freshened Approximation can in most cases be achieved by plantarflexion If this is not possible the knee should be flexed up to a right or acute angle, this approximates the ends of the gastrocnemius muscle by 10 cm (see Vol I/figs 1—6) Should approximation of the tendon stumps still be impossible, a 6 to 8 cm long, 2 cm wide flap is cut from the proximal stump and the gastrocnemius tendon, swung over the gap, and sutured to the distal stump No attempt should be made to bridge the gap by silk sutures or free fascial grafts since they will usually be cast off

Tendon Suture in Cases Bridged by Scars In ruptures of more than 6 months standing the gap is usually filled with firm scar tissue which may be so smooth that the site of rupture can hardly be identified The scar tissue must not be removed but should be cut through for 8 cm in a frontal plane in Z-shape (forming a step in each end) In extreme plantarflexion of the foot and extreme flexion of the knee both ends are pulled together, until they overlap as much as possible and are sutured The wound is closed as in fresh cases

Compression Bandage and Bed Cast The wound is covered by gauze moistened with Peruvian balsam At extreme flexion of the knee a sterile hemp cord is placed on the ventral side of the foot and lower leg (see p 1656) A compression bandage is put around the leg to avoid hemorrhage Then the patient is turned into the supine position and a lower leg cast is applied as described on page 1920 The plantarflexion should amount to 110° to 115° and should not be extreme The cast must be split over the whole length of the hemp cord immediately, i e, before the patient leaves the operating room The cast is fenestrated over the wound and the leg is elevated on a Braun splint or a pillow

Removal of Stitches The stitches should be removed through the window 10 to 12 days after operation i e, one day before application of the walking

cast If the skin has become macerated, the wound should be left without a dressing until the skin is dry

Short Leg Walking Cast This cast is applied at plantarflexion of 100° to 105° as described on page 1926 A walking stirrup is mounted When the cast has set a few hours later, the patient can walk and can resume his work after a few days if it does not require hard labor (see p 1893)

Walking is the best *exercise therapy* as long as the patient feels no pain

Duration of Immobilization The short leg walking cast is removed 6 weeks after operation

Further Treatment After removal of the walking cast an Unna s paste bandage *is applied from the web of the toes up to the knee for 2 to 4 weeks* No further after-treatment is necessary since walking and the normal use of the leg is the best exercise therapy

Inappropriate Methods of Treatment Massage, passive movements, hot or cold compresses, short waves, radiant heat, ointments, plaster casts, different bandages or appliances are of no use since the tendon will heal with lengthening

III TEARS OF THE CALF MUSCLES

Etiology Tears of the calf muscles occur in tennis As in rupture of the Achilles tendon a sudden pain is felt in the calf Moving on tiptoe is impaired There is local tenderness over the calf but no gap Swelling is little

Treatment We apply an Unna's paste bandage from the web of the toes up to the knee Thus, the complaints will cease, as a rule, within 1 to 3 weeks

Questions We Should Ask Ourselves in Order to Avoid Failures When Examining and Treating Ruptures of the Achilles Tendon

1 Have I thought of a rupture of the Achilles tendon if a patient felt a sudden pain like a blow in the region of the Achilles tendon?
2 Have I observed the patient s tiptoeing?
3 Have I tested the power of plantarflexion?
4 Have I looked for a gap in the Achilles tendon?
5 Have I sutured the tendon if the diagnosis was certain?
6 Have I delayed the operation in fresh cases until the third week after injury?
7 Have I used an incision just medial to the Achilles tendon and not a curved lateral incision in order to avoid damage to the skin nerves?
8 Have I left the ventral peritendineum intact?
9 Have I used an interlacing suture at both ends of the ruptured tendon and not a single U-suture which would cut through?
10 Have I added fine sutures?
11 Have I spread the tendon of the plantaris muscle and sutured it over the site of rupture in order to achieve a smooth surface?
12 Have I, in old cases, plantarflexed the foot and flexed the knee to approximate the tendon stumps (Vol I/figs 1—6)

13 Have I formed a centrally pedicled flap of tendon if approximation of the stumps proved impossible?
14 Have I abstained from using silk threads or free fascial grafts to bridge the gap since they, as a rule, would slough out?
15 Have I, after closure of the wound, applied a cast at 110° to 115° plantarflexion and not at extreme foot drop position?
16 Have I split the cast immediately, i e, before leaving the plaster room, and cut a window over the operational wound?
17 Have I removed the stitches one day before application of the walking cast?
18 Have I applied a walking cast 10 to 12 days after operation?
19 Have I removed the walking cast 6 weeks after operation?
20 Have I, after removal of the walking cast, applied an Unna s paste bandage for 2 to 4 weeks?

Results of 36 Operated Subcutaneous Ruptures of the Achilles Tendon

H R Schonbauer[1] studied our 36 operated ruptures of the Achilles tendon of the 24 years from December 1, 1925 to December 31, 1949 In 1954 he re-examined a further series of 40 cases We have treated 29 more cases meanwhile so that the total of our operated cases was 105 by December 1955

Of the first 36 cases, 19 patients were re-examined, 8 answered questionnaires, 2 died, 7 were prevented from coming Of the patients who were not re examined we have at hand the findings when they were discharged from treatment

The period between operation and re examination (or answering the questionnaire or findings on discharge) varies from 5 months to 13 years

All surgical wounds healed by first intention, 16 patients developed thread fistulae later on In five of them the fistulae closed after operative removal of the threads The remaining 11 fistulae closed by themselves One cannot be certain that penicillin prevents the occurrence of thread fistulae Of seven of our patients who were given penicillin, thread fistulae developed in two There was no increase or decrease in frequency of the thread fistulae In the first third of our cases they occurred five times, in the second third five times and in the third third six times The thread fistulae did not influence the result of operation

Immobilization in the split lower leg bed cast lasted between 7 and 25 days, an average of 12 days A lower leg walking cast was applied for 14 to 39 days, an average of 27 days Thus, the total duration of immobilization after the operation amounted to an average of 39 days

At the time of re-examination three patients complained of occasional pain in the tendon region One patient had felt burning pain in the tendon as early as nine months before the accident and for 3 years has felt the same pain in the other Achilles tendon The second patient suffered from venous thrombosis in the calf of the injured side, so the pain was not necessarily from the

[1] Schonbauer H R Gedeckte Risse großer Sehnen am Bein 48 Heft 3 Unfallheilk 200—203 1954

tendon The third patient filled in the questionnaire as early as 5 months after operation

Two patients complained of superficial sensory disturbances in the region of the scar In 5 patients the scar was partly adherent in its proximal part but did not impede mobility In 7 patients the site of suture was somewhat thickened The gait was normal in all patients, three patients become tired after walking long distances These three patients are over 50 years of age One patient tires when wearing high heels, she is also over 50

Toes, subtalar joint, knee and hip of all patients were actively free through their full range of movement In 7 patients dorsiflexion of the talocrural joint was limited by 10° In 3 patients plantarflexion was limited by 10° In one patient plantarflexion was limited by 15° A thread had been extruded 17 days before the re-examination, 4 weeks later another thread fistula broke up which closed after operative treatment Three patients showed increase of dorsiflexion by 5° and decrease of plantarflexion by 5° One patient's mobility of the talocrural joint was better than on the uninjured side, she is a tailor working at a sewing machine

The circumference of the calf was decreased by 5 to 15 mm in 8 patients (including 3 old cases), by 20 to 25 mm in 7 patients (including 5 old cases) In five patients the calf of the injured side was thicker (including two cases of thrombosis unrelated to the operation)

Twenty-one of our 36 patients could resume their old work as soon as they had their walking cast on Seven took up their work within the first two weeks after removal of the cast, three after three weeks, one patient after six weeks two after eight weeks One patient had a pulmonary embolism two months after operation He resumed work four months after this complication

Four months after operation most patients resumed their old sports Some of our patients participated in climbing and ice tours 10 weeks after operation and were not hindered in their work as skiing instructors In the hurdle race one patient equaled the time in which she ran it as champion of Austria and as fifth at the Olympic Games in 1948 Another patient could resume her work as leader of a ballet six weeks after operation

112 RECURRENT DISLOCATION OF THE PERONEAL TENDONS

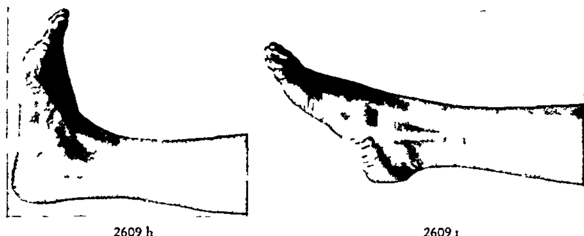
Etiology Supination-adduction and internal rotation of the foot may cause (1) supination-subluxation at the ankle joint (figs 2678—2682), (2) supination fractures of the medial and lateral malleolus (figs 2683—2686), or (3) rupture of the retinacula peroneorum and dislocation of the peroneal tendons Instead of a narrow groove behind the lateral malleolus a wide bag like tendon sheath forms which covers the lateral malleolus

Diagnosis The peroneal tendons slip forward when the foot is *dorsiflexed* or adducted (supinated) In some patients the dislocation is present *in dorsiflexion* as well as in plantarflexion (figs 2609 h, i)

Treatment The lateral malleolus is exposed through a curved *incision* under spinal or general anesthesia and in a bloodless field After *severance* of skin and fascia a markedly stretched tendon sheath is exposed, the medial wall of which covers the lateral malleolus From the front of the lateral

malleolus a 1 to 2 mm thick and 10 mm wide piece of bone is chiselled off, swung backward over the peroneal tendons and fixed with sutures Thus, a firm retinaculum has been regained A short leg temporary bed cast is applied and split immediately throughout its full length Ten days later a short leg walking cast is applied which will be removed 6 weeks after operation and will be followed by an Unna's paste bandage

We have observed no recurrence after this operation



2609 h 2609 i

FIG 2609 h i—Dislocation of the peroneal tendons They take their course over instead of behind the lateral malleolus

113 INJURIES OF THE ANKLE JOINT

The injuries of the ankle joint with fractures of the malleoli, rupture of ligaments, and dislocations are among the commonest and most important accidents Their variety is manifold Either the medial or more frequently the lateral malleolus may be fractured, or both malleoli at the same time Ruptures of ligaments may occur or avulsion fractures of ligamentous insertions The posterior or much more seldom the anterior margin of the lower end of the tibia may be sheared off In severe ruptures of ligaments partial or complete dislocation of the talus and the foot bones occurs in most cases backward and outward The dislocation may also be outward, inward, backward and in rare cases forward

114 FRACTURES OF THE MALLEOLI

Etiology and Classification of the Malleolar Fractures

Fractures of the malleoli as a rule result from *indirect* violence such as slipping or falling and are due to excessive compression, angulation, or torsion or to excessive traction on ligaments Generally several or all four mechanisms act simultaneously Fractures caused by *direct* violence, e g, the impact of a heavy object just above the ankle are rare (2—4%)

The type of the malleolar fracture and its displacement depend on the direction of the acting direct or indirect force and on the position of the foot (dorsal or plantar flexion pronation or supination, external or internal rotation), of the knee, especially of the hip joint, and of the whole body

during the trauma. The types of fracture depend on the rapidity of the fall, on the weight and age of the patient, on the density of his bones, on the general strength and actual tonus of his muscles, as well as on the quality of the ground (even, uneven, hard, soft). The force of the accident does not act simply according to the formula Force = Mass × Velocity, it also depends on the above mentioned circumstances, but especially on the actual reaction of the muscles. The different injuries follow certain patterns. Fracture of the os calcis, as a rule, follows a free fall. The force resulting from the product of mass and 'velocity' acts as pure compression and, in contradistinction to a malleolar fracture, without torsion or angulation. During the war many fractures of the os calcis were caused by a force from underneath, viz., land and submarine mines.

The terminology of the positions of the ankle joint and of the whole foot under normal conditions and after injuries, as well as the position of the forefoot in flat foot, club foot, and pes cavus, namely, pronation and supination, abduction and adduction, valgus and varus, external and internal rotation, and plantar and dorsal flexion have been described on pages 1811—1819. It should be noted that pronation and abduction (or supination and adduction) describe a certain kind of motion whereas valgus (or varus) describes the resulting position. How the movements of the foot, the knee and the hip influence each other has been discussed on pages 1505—1507.

There are many *classifications* of malleolar fractures. I consider that of Lauge-Hansen to be the best. To my knowledge Reimers[1] was the first in German literature to call attention to Lauge-Hansen's fundamental experimental, roentgenological and clinical work.

Lauge-Hansen [2-8] proved by experiments on fresh lower extremities obtained by below or above knee amputations that regular types of fractures, ruptures of ligaments, and dislocations occur under certain conditions. Four important fundamental types have been differentiated and classified according to mechanism and severity. The mechanism of ruptures of ligaments and avulsion fractures of the ligamentous insertions is also described by Lauge-Hansen.

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[1] Reimers: Die Brüche des fußnahen Unterschenkelabschnittes. Langenbeck's Arch. 1953 and D. Zschr. Chir. *276*, 256—277. Kongreßbericht 1953.

[2] Lauge-Hansen, N.: Ankelbrud (Knöchelbrüche dänisch). Kopenhagen: Verlag Einar Munksgaard 1942.

[3] — Fractures of the Ankle. Analytic Historical Survey as the Basis of New Experimental Roentgenologic and Clinical Investigations. Arch. Surg. *56*, 259 1948.

[4] — Ligamentous Ankle Fracture. Diagnosis and Treatment. Acta Chir. scand. *97*, 544 1949.

[5] — Fractures of the Ankle. II. Combined Experimental-Surgical and Experimental Roentgenologic Investigations. Arch. Surg. *60*, 957—985 1950.

[6] — Fractures of the Ankle. III. Genetic Roentgenologic Diagnosis of Fractures of the Ankle. Roentgenology *71*, 456—471 1954.

[7] — Fractures of the Ankle. IV. Clinical Use of Genetic Roentgen Diagnosis and Genetic Reduction. Arch. Surg. *64*, 488—500 1952.

[8] — Fractures of the Ankle. V. Pronation-Dorsiflexion Fracture. Arch. Surg. *67*, 813—820, 1953.

His four fundamental groups are

1 Supination external rotation fractures (figs 2611 c, 2616, 2633, 2634, 2687, 2688) These are the commonest malleolar fractures They comprise 68 5% of Lauge-Hansen's 300 clinical cases
2 Supination-adduction fractures (figs 2617, 2625, 2635) represent 15 5%
3 Pronation-external rotation fractures (figs 2610 a, 2611 a, 2616 a, 2636, 2695, 2703, 2704) represent 8 3%
4 Pronation-abduction fractures (figs 2611 b, 2617 a, 2656, 2670) represent with 6%

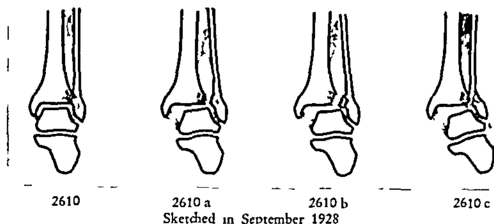


Fig 2610 – Section through the talocrural subtalar and lower tibio fibular joint

Fig 2610 a – Rupture of the anterior ligament of the lower tibio fibular joint and of the deltoid ligament Subluxation of the foot outward Caused by internal rotation of the body while the pronated foot is held fast i e external rotation of the foot in relation to the crus (Pronation external rotation fracture Stage 4 according to Lauge Hansen) Compare with figs 2622 and 2623

Fig 2610 b – Rupture of the lower tibio fibular joint with avulsion of an antero lateral lamella (tuberculum anterius tibiae) from the tibia and rupture of the deltoid ligament with subluxation of the foot outward The mechanism is the same as in fig 2610 a (Pronation external rotation fracture Stage 4 according to Lauge Hansen)

Fig 2610 c – Torsion fracture of the lateral malleolus at the level of the talocrural joint with rupture of the anterior tibio fibular ligament and the deltoid ligament Subluxation of the foot outward Caused by internal rotation of the body while the supinated foot is held fast i e external rotation of the foot in relation to the crus as in figs 2633 2634 (supination external rotation fracture Stage 4 according to Lauge Hansen) Compare with figs 2718 2720 2722 2747

Lauge-Hansen has also described a rare fifth group which he calls pronation-dorsiflexion fracture (fig 2547) occurring by forced compression in the long axis of the crus at dorsiflexion of the foot I would rather call this type of fracture a *supination-dorsiflexion fracture* whereas figures 2531 2541 2557 and 2565 show true *pronation-dorsiflexion fractures*

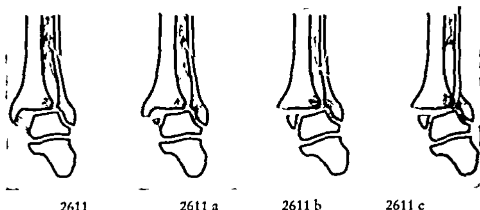
Figures 2521, 2523 and 2538 show pure *plantarflexion fractures* and their etiology

The figures 2522, 2524, 2535, 2536 show pure *dorsiflexion fractures* and their mechanism These two types of fractures, the group caused by compression

in the long axis of the crus, and the severe comminuted fractures described on pages 1819—1842 have not yet been studied by Lauge-Hansen

Lauge-Hansen carried out his experiments as follows

1 To produce *the four stages of the supination-external rotation fracture* the femoral stump of the amputated lower extremity before rigor mortis has



2611 2611 a 2611 b 2611 c

FIG 2611 —Rupture of the deltoid ligament of the anterior tibio fibular ligament and of the interosseus ligament Torsion fracture of the fibula a hand s breath above the ankle and subluxation of the foot outward Caused by internal rotation of the body while the pronated foot is held fast as in figs 2610 a and b The result is external rotation of the foot in relation to the crus (pronation external rotation fracture Stage 4 according to Lauge Hansen)

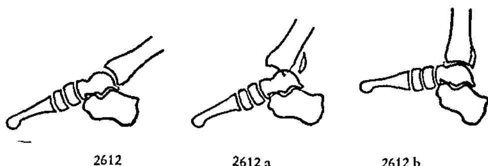
FIG 2611 a —In contradistinction to fig 2611 there is no rupture but an avulsion fracture of the medial malleolus Otherwise this is the same situation as in fig 2611 (pronation external rotation fracture Stage 4, according to Lauge Hansen) Compare with figs 2638 2639 2675 2695 2703 2704)

FIG 2611 b —Bending fracture of the fibula 5 cm above the ankle with a lateral wedge shaped fragment (bending wedge) Rupture of the anterior tibio fibular ligament Avulsion fracture of the medial malleolus and subluxation of the foot outward Caused by direct impact upon the lateral side of the lower leg Pronation (abduction) fracture stage 3 according to Lauge Hansen Compare with fig 2670

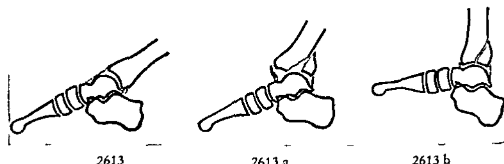
FIG 2611 c —Torsion fracture of the lateral malleolus at the level of the ankle joint rupture of the anterior tibio fibular ligament Avulsion fracture of the medial malleolus and subluxation of the foot outward Caused by internal rotation of the body while the supinated foot is held fast This is the same injury as in fig 2610 c with the only difference that the deltoid ligament is not ruptured but the medial malleolus is avulsed The mechanism is external rotation of the foot as in figs 2633 2634 (supination external rotation fracture stage 4 according to Lauge Hansen) Compare with figs 2687 2707 2724, 2753 In figs 2610 a 2610 b 2611—2611 b the tibiofibular syndesmosis is torn and thus the intermalleolar distance increased In fig 2610 c the distance between the malleoli is also increased but with intact tibiofibular syndesmosis In figs 2611 a—c both malleoli have remained in contact with the talus

developed is fixed in a vise The foot is fixed in extreme supination and under compression in the long axis of the crus, which corresponds to the body weight, rotated outwards By these movements the anterolateral ligaments of the ankle joint are markedly tightened At a certain stage of the external rotation a crack is heard Dissection reveals detachment of the ligamentum tibiofibulare anterius from the anterior tubercle of the tibia or the lateral malleolus, a thin bony shell the size of a large bean, is torn off This is Stage 1

Further external rotation[1] of the supinated foot widens the tibiofibular syndesmotic space and leads to a torsion fracture of the distal end of the fibula The fracture line commences anteriorly at the line of the talocrural



FIGS 2612—2612 b—Origin of a fracture dislocation backward and outward When the fibula is not sketched one cannot decide from the tibia alone whether it is a supination or a pronation external rotation fracture Both types of fracture occur with internal rotation of the lower leg together with the whole body while the foot is held fast i e external rotation of the foot in relation to the lower leg The tibia slips inwards and forwards so that the talus comes to lie latero posteriorly A flake of bone is torn form the posterior margin of the tibia If this flake of bone is displaced upward it can be pulled down by dorsiflexion of the foot This extreme dorsiflexion is only used reduction When the cast is applied the foot should be at angle of 95° to 100° This fracture can as a rule easily be retained in good position by the usual lower leg cast (see roentgenograms figs 2687—2690 and 2695—2698)



FIGS 2613—2613 b—Mechanism of posterior dislocation with breaking off of a large posterior wedge The ligaments in front of the ankle are torn by the maximal plantar flexion and the talus produces a shearing off of the posterior half of the tibial articular surface If the knee is flexed (figs 2644—2648) the big posterior wedge can be reduced by traction in the long axis of the crus and by firm dorsiflexion of the foot The good position can only be maintained by continuous traction (figs 2691—2694 2699—2702) by screws (fig 2537) or by crossed wires

joint and runs dorsally at first almost horizontally and later on more obliquely and backward This is Stage 2

If the external rotation of the supinated foot is continued the talus sub luxates outwards and backwards, and shears off and tears a fragment of varying

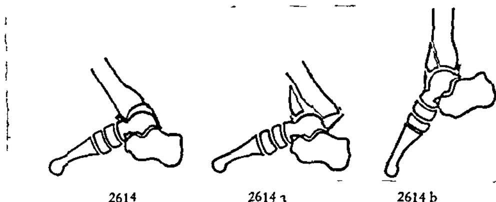
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[1] Lauge Hansen calls external rotation eversion and speaks of supination *eversion* For the sake of clarity the term supination *external rotation* is used here

size from the dorsal lip of the tibia, which is connected with the lateral malleolus by the ligamentum tibiofibulare posterius This is Stage 3

Further external rotation of the supinated foot is followed by another crack The deltoid ligament is torn from the medial malleolus (figs 2610 c, 2633, 2634) and there is a diastasis between the medial malleolus and the talus (medial widening of the "malleolar fork) This is Stage 4 The foot is then attached to the crus only by the soft parts Joint capsule and all ligaments which normally tie the foot to the crural bones are detached from them with larger or smaller fragments The four stages are shown in figure 2616

Actually the four stages of the supination external rotation fracture occur within a fraction of a second Supination of the foot is a result of hip abduction With the foot held fast in this (supinated) position the body rotates

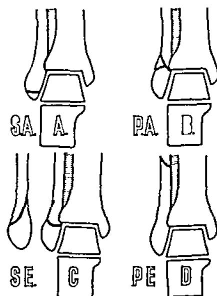


Figs 2614—2614 b —Origin of a forward displacement at the ankle with shearing off of an anterior wedge caused by a fall from a height the body weight going forward so that the foot is in extreme dorsiflexion The posterior ligaments are torn The tibia slips back as in fig 2522 and the anterior half of the distal tibial articular surface is sheared off The anterior fragment still attached to ligaments is restored to position by firm plantarflexion This fracture can only be retained in good position by screws (fig 2525 2536 a)

inwards, i e , outward rotation of the foot in relation to the body We have known that most ankle fractures are external-rotation fractures That most of these fractures occur in supination has now been clarified by Lauge-Hansen Due to suddeness of the trauma all four stages sometimes do not develop completely Thus some bimalleolar fractures of the supination external rotation type are encountered without significant ligamentous lesions

2 To produce *the two stages of the supination-adduction fracture* the amputated lower extremity is placed with the crus vertically The foot is turned at an angle of considerable supination and fixed in this position to a horizontal support by nails through the medial and lateral edges The heel region is also fixed by nails medially and laterally When the crus has been moved medially so that it forms an angle of 45 degrees with the support, a crack is heard On dissection, detachment of the ligamentum calcaneofibulare and talofibulare posterius from the tip of the lateral malleolus (fig 2678) or avulsion of a small bone shell (fig 2680) is seen or a transverse horizontal fracture through the middle of the lateral malleolus or at the level of the ankle joint or closely above it (fig 2734) This is stage 1

When the medial movement of the crus is continued pressure of the talus shears off the medial malleolus obliquely (fig 2625) or vertically (figs 2683, 2684) This is stage 2 If the movement is continued, a transverse cutaneous tear *is produced at the lateral malleolus and complete medial dislocation of the foot* results (figs 2539, 2721, 2734) Sometimes small fragments are sheared off from the medial part of the distal articular surface of the tibia The two stages are shown in figure 2617



2615

Diagrams showing the characteristic localization and form of the fibular fracture decisive for each of the four types of fracture of the ankle (from Lauge Hansen) A Transverse fracture distal *to the ankle joint in the supination adduction fracture* (S A) B Flexion fracture with lateral flexion wedge just above the ankle joint in the pronation abduction fracture (P A) C Torsion fracture at the level of the ankle joint in the supination external rotation fracture (S E) D Torsion fracture of the fibula 8 cm proximal to the ankle joint in the pronation external rotation fracture (P E)

Actually the supination-adduction fracture occurs, as a rule, by indirect force, namely, by a fall from at least 50 cm upon the lateral margin of the foot (fig 2686) If the falls are from a lesser height the patients are carrying *heavy objects* (*fig 2683*) *This fracture may also occur during impact* of a vehicle against an obstacle if the foot is in marked supination (fig 2539) It may also be caused by direct violence, e g, the impact of a heavy tree against the middle of the lower leg (fig 2734) In severe displacement the medial part of the distal articular surface of the tibia is sheared off and displaced cranially (figs 2527, 2539)

3 To produce *the four stages of the pronation-external rotation fracture* the femur of the amputated lower extremity is fixed in a vise The foot is fully pronated and rotated outwards while pressure equivalent to the body-weight is applied in the long axis of the crus A crack is felt, indicating the occurrence of a transverse fracture of the medial malleolus (figs 2611 a 2616 a, 2695)

or in rare cases only rupture of the deltoid ligament (figs 2610 a, 2610 b, 2622, 2633) This is stage 1

If external rotation of the pronated foot is increased, the ligamentum tibiofibulare anterius is detached carrying with it a small bony flake from the tuberculum anterius tibiae or from the lateral malleolus In contrast to the supination external rotation fracture also the anterior part of the ligamentum interosseum is torn This is stage 2

Further external rotation of the pronated foot leads to a torsion fracture of the fibula 6 to 8 cm above the tip of the malleolus (figs 2611 a, 2695, 2703) or still higher (figs 2623, 2637) This is stage 3

If external rotation is continued the ligamentum tibiofibulare posterius is strongly tensed, the talus, dislocated far laterally, tears a piece of bone of varying size from the posterior lip of the tibia (fig 2695) Extensive laceration of the ligamentum interosseum causes dislocation of the talus into the space between tibia and fibula (figs 2703, 2733) The talus moves with the foot forward This is stage 4

Actually the four stages of the pronation-external rotation fracture occur in a fraction of a second when the body, while the femur is adducted in the hip, is suddenly rotated inwards, i e, away from the fixed foot

4 To produce the *three stages of the pronation-abduction fracture* the foot is fixed on a board by nails near the proximal phalanx of the great toe and through the dorsal medial part of the heel The crus is moved laterally When it forms an angle of about 60° with the support a crack is heard, indicating a transverse fracture of the basal part of the medial malleolus This is stage 1

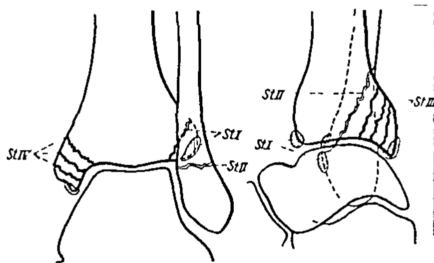
Further angulation of the crus causes rupture of the ligamentum tibiofibulare anterius with avulsion of a small and rupture of the ligamentum tibiofibulare posterius with avulsion of a bigger piece of bone from the tibia This is stage 2

Further angulation produces an audible crack caused by a transverse fracture of the fibula 1 to 2 cm above the ankle joint (fig 2656) In some cases the fracture level lies higher (fig 2672) A bending wedge is broken out lateral to the fracture gap This is stage 3

Clinically the pronation-abduction fracture occurs when a person catches his feet in a ladder or between two rails and his body falls outwards (fig 2731) Or a direct force may hit the outer side of the lower leg while the foot is fixed, e g, the impact of falling wooden boards (fig 2672) Depending on the severity of the force stage 1, 2 or 3 may occur

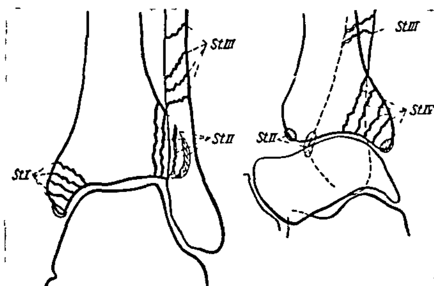
Comparison of the Sequence of the Four Stages of the Supination-External Rotation Fracture and the Pronation-External Rotation Fracture

Supination	Pronation
1 Rupture of the ligamentum tibiofibulare anterius	1 Avulsion of the medial malleolus
2 Torsion fracture of the lateral malleolus at the level of the ankle joint	2 Rupture of the ligamentum tibiofibulare anterius and ligamentum interosseum
3 Shearing off and avulsion of the posterior lip of the tibia	3 Torsion fracture of the fibular shaft 6 cm above the tip of the malleolus or higher dislocation of the talus
4 Dislocation of the talus and avulsion of the medial malleolus	4 Shearing off or avulsion of the posterior lip of the tibia



2616

The four stages of supination external rotation fracture according to Lauge Hansen The varieties found in experiments are also shown The hatched areas indicate sites of ligamentous avulsion The stages are numbered according to the sequence of occurrence



2616 a

The four stages of pronation external rotation fracture according to Lauge Hansen *In reality* the fracture line of the torsion fracture of the fibula runs steeper

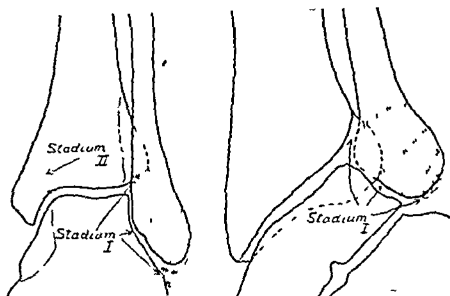
Disruption of the Malleolar Fork (Mortise)

There are four types of disruption of the malleolar fork

1 Rupture of the tibiofibular syndesmosis alone with fracture of the medial malleolus and high fracture of the fibula (figs 2611 a, 2611 b 2621, 2638)

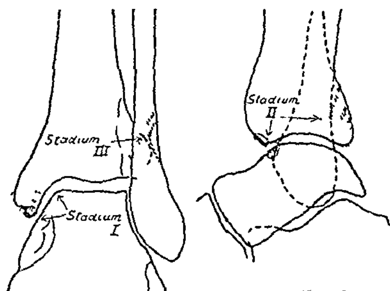
2 Rupture of the tibiofibular syndesmosis with rupture of the deltoid ligament and high fracture of the fibula (figs 2610 a, 2610 b 2611, 2620 2622)

3 Rupture of the deltoid ligament with torsion fracture of the lateral malleolus at the level of the ankle joint (fig 2610 c)



2617

The two stages of the supination adduction fracture according to Lauge Hansen



2617 a

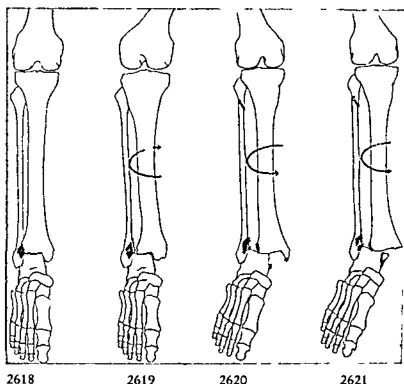
The three stages of the pronation abduction fracture according to Lauge Hansen

4 Rupture of the ligamentum calcaneofibulare and talofibulare with shearing fracture of the medial malleolus (fig 2625) A knowledge of these injuries is important as they are mainly ruptures of the ligaments As severed ligaments necessitate a longer period of time for healing than fractured bones, immobilization must be maintained for a sufficiently longer period

1 *Disruption of the malleolar fork due to rupture of the tibiofibular syndesmosis and the interosseous membrane alone* occurs only if the fractured medial malleolus remains in contact with the talus and is dislocated outwards with it Tibia and fibula are separated while both malleoli have remained in contact with the talus This injury is found only in the stages 3 and 4 of the

pronation external rotation fracture (figs 2611 a, 2621, 2638, 2675, 2695, 2703, 2733) and in stage 3 of the pronation-abduction fracture (figs 2611 b, 2670)

2 *Disruption of the malleolar fork due to rupture of the tibiofibular syndesmosis, of the interosseous membrane, and the deltoid ligament* occurs only



2618 2619 2620 2621

Sketched in June 1932

Fig 2618—Normal foot and lower leg

Fig 2619—The foot being held firm and the body rotated outwards only the tibia is rotated if the ligaments hold between fibula and talus The anterior outer edge at the lower end of the tibia is torn off and the ankle joint is loosened

Fig 2620—The foot being fixed and the body rotated inwards rupture of the ligaments between the medial malleolus and the talus and between the tibia and fibula occurs The foot is dislocated laterally There is also a torsion fracture of the upper end of the fibula while a small piece of bone is torn from the posterior angle of the tibia Compare with figs 2622 2623 2624 (pronation external rotation fracture according to Lauge Hansen) This is the severest degree of intermalleolar separation

Fig 2621—The bone may be torn off on the medial side of the ankle instead of the ligament This is a slight degree of intermalleolar separation

in stages 3 and 4 of the pronation-external rotation fracture if the medial malleolus has not been fractured There is gaping between the tibia and fibula, and between talus and medial malleolus (figs 2610 a, 2610 b, 2611, 2620, 2622, 2623)

3 *Disruption of the malleolar fork due to rupture of the deltoid ligament alone* occurs only in stage 4 of the supination-external rotation fracture if, besides the torsion fracture of the lateral malleolus at the joint level, the deltoid

ligament is torn and not the medial malleolus There is gaping between talus and medial malleolus whereas tibia and fibula have remained in normal relation (figs 2610 c, 2634, 2666, 2718, 2720, 2747)

4 *Disruption of the malleolar fork due to rupture of the ligamentum talofibulare and calcaneofibulare alone* occurs only in stage 2 of the supination-adduction fracture, if only the medial and not the lateral malleolus has been fractured There is gaping between the fibula and the talus which remains in contact with the fractured medial malleolus (fig 2625)



2622

FIG 2622 left—Partial dislocation of the foot outwards The attachment of the talus to the lateral malleolus is preserved The joint between the tibia and the fibula is torn A small piece of bone is avulsed from the medial side of the talus Torsion fracture of the fibular neck Compare with fig 2620 Pronation external rotation fracture according to Lauge Hansen
FIG 2622 right—The same from the side Foot displaced backwards A small extra articular fragment is broken off the posterior margin of the tibia and the posterior process of the talus is fractured This type of dislocation must be treated for 16 weeks in an unpadded walking plaster cast after exact reduction Severest degree of intermalleolar separation

Clinical Examination of Ankle Fractures

The clinical examination must precede the roentgen examination in all cases

History (Anamnesis) While looking at the patient the surgeon asks how the accident happened and hears that the patient, e g, slipped while walking on even ground or when skiing and fell (indirect fracture) or that a heavy object fell upon the ankle joint (direct fracture) Some patients relate that the tip of the foot pointed outwards or inwards after the accident and that they themselves rotated the foot forwards They describe the occurrence of a sudden severe pain in the ankle region and that they were almost unable or completely unable to stand on the injured foot

Inspection One determines whether the patient is pale or is in shock and whether he complains of pain Without removing the patient s clothing or shoes one notes whether the foot is twisted or angulated outward or inward

Then, the patient is stripped of his clothes and shoes in a warm room so that *both* lower limbs can be examined and compared *During this the patient must be protected from chilling* Meanwhile the patient s name, age, profession, address, body height and weight are recorded

Examination for Changes of Color, External Shape, and Skin Temperature One determines whether the ankle joint is swollen, whether the skin is pale, blue or normal, whether there are signs of excoriations, hematomas, or blisters,



2623

Fig 2623—Subluxation of the talus outward avulsion of a small bone shell from the posterior margin of the tibia and high torsion fracture of the fibula Sustained by a 30 year old merchant when skiing Compare with fig 2620

whether there is abnormal deviation in external shape of the ankle towards posterior, anterior, medial (fig 2635) or lateral, and whether there are unusual bony prominences (fig 2633) Then a hand is placed alternatively on one and the other ankle joint and the feet to determine whether the injured foot is warm or cool

Examination of Pulse and Reflexes After having recorded the patient s general condition the dorsalis pedis and posterior tibial pulses are taken bilaterally In total posterior or anterior dislocation as in figures 2789—2792 the injured foot is pale and cool and no pulse is palpable on the injured side In this condition reduction should be performed soon, as well as in a case where a fragment projects under stretched and pale skin (fig 2633) Then the patellar tendon reflex on the sound side is tested The form and diameter of

the pupils are noted and their reactions to light and convergence are tested In tabes dorsalis the reflexes are absent and the pupils are narrow and do not react to light Tabetic patients may suffer severe complications following slight injuries, even amputation may become necessary in rare instances (figs 2781—2784)

Examination of Joint Motion The patient is told to move, first on the sound then on the injured side, the toes, the subtalar and ankle joints, then the knee and hip joints The latter two joints should only be moved if no considerable pain is produced The toes are stiff in posterior or anterior total dislocation Motion of the ankle joints is limited in all ankle fractures The amount of limitation of motion is measured in degrees and compared with the sound side



2624

Fig 2624 —Same case after reduction The malleolar fork is closed On account of malleolar separation at the inner and outer malleolus immobilization of the joint must be continued for 12 weeks

Palpation Only after having recorded all results of the inspection and of the examination of reflexes and joint mobility should one again touch the patient One looks for the sites of maximum tenderness by palpating, according to the patient s statements, from proximally and distally towards the center of tenderness In severe injuries, as a rule, the whole ankle region is very tender due *to the multiple osseous and ligamentous lesions* In *slight injuries* the fracture line, e g , in the lateral malleolus can be distinctly determined

Examination of the Firmness of the Ankle Joint and Test for Impingement of the Talus Against the Medial Malleolus The surgeon grasps the lower leg proximal to the ankle region with one hand and the foot distal to the ankle region with the other hand and tries to move the foot gently inwards and outwards, backwards and forwards, without eliciting significant pain If only the lateral malleolus is fractured and the deltoid ligament ruptured (fig 2666), distinct impingement of the talus against the medial malleolus can be felt

Examination for Crepitation Crepitation can be felt in some cases but can be heard only rarely One should never try to elicit crepitation by excessive painful movements

Roentgen Examination of Ankle Fractures Under Local Anesthesia

The roentgen examination should be carried out only after the clinical examination

Most ankle fractures come to admission in a more or less reduced condition Some patients straighten their twisted or angulated foot themselves or this is done at first aid X-ray technicians often put the foot as straight as possible for the exposures To determine the period necessary for immobilization one should know the original displacement, i e , the extent of the ligamentous lesions To restore the original displacement the ankle joint should be anesthetized locally after the clinical examination and before the roentgenograms



2625 December 29 1948

2626 September 18 1952

FIG 2625 —Supination adduction fracture Stage 2 according to Lauge Hansen Sustained by a 28 year old driver who was hit by a heavy barrel on the medial side of the left supra malleolar region Excoriations were present In the roentgenogram taken in forced supination the joint space gapes between talus and lateral malleolus a sign of ligamentous avulsion from the tip of the lateral malleolus Unusually severe swelling and formation of blisters on the lateral side of ankle joint Since accurate reduction could not be secured open reduction and screwing was performed three weeks after the accident when the blisters had healed Two weeks later lower leg walking cast which was removed 10 weeks after operation or 13 weeks after the accident

FIG 2626 —Same case 3¾ years later Bony union in good position Subtalar joint limited by one quarter ankle joint freely mobile Asymptomatic

are taken In severe displacement and swelling it will suffice to inject from the front 20 cc of 2 per cent Novocain solution into the joint After injection of 5 cc the syringe should be withdrawn If blood stained fluid returns one has punctured the hematoma In a fracture of both malleoli with slight displacement both fracture sites must be injected The injection is followed immediately or within a few minutes by complete freedom from pain and relaxation of the muscles Then the foot can be displaced outwards (figs 2637 2638), inwards (fig 2625, 2678 2679) backwards or forwards, depending on the type of injury This is especially important in medium degree cases of widened mortise where, under local anesthesia, the impingement of the talus against the medial malleolus can easily be elicited and where the gaping malleolar fork can then be demonstrated in the roentgenogram This

displacement should not be carried out with excessive force in severely damaged joints Local anesthesia relieves not only pain but abates also shock This helps to win the patient's confidence

Roentgen Examination of the Normal and the Reduced Ankle Joint

Whereas with most other joints the limb is placed exactly anteroposteriorly and exactly laterally, i e, in the two main planes, this is not the case with the ankle joint because its axis runs obliquely from medio-ventrally to latero-dorsally since the lateral malleolus lies further dorsally than the medial one

Anteroposterior Roentgenogram of the Ankle Joint The leg should be rotated inwards through 15° to 20° in order to show distinctly the joint space between the talus and the medial malleolus This is attained if in the supine patient the lateral margin of the foot is vertical (fig 2627) The sole of the foot is propped with a sandbag in order to avoid supination of the forefoot (fig 2686 f) Only with this 15° to 20° internal rotation of the lower extremity can we decide that a lateral subluxation (fig 2666) has been completely reduced (fig 2668) At 25° to 35° internal rotation (fig 2628) the joint space between the talus and the lateral malleolus is shown distinctly whereas the contours of the talus and medial malleolus overlap In this marked internal rotation of 25° to 35° the shadow of the tuberculum anterius tibiae no longer overlaps that of the fibula This condition was misjudged by some surgeons for a widening of the mortise and therefore treated by screw fixation At external rotation of 10° (fig 2629) and more and at internal rotation of more than 35° the joint space can be judged neither at the medial nor at the lateral malleolus since their shadows overlap with the talus In figures 2378 c and d the angle between the medial and lateral margin of the foot can be seen The amount of internal or external rotation of the leg can be judged from the tibio-fibular distance It is the wider the more the leg is rotated inwards (fig 2628) and the narrower the more the leg is rotated outwards (fig 2629) At 20° external rotation it disappears completely These conditions should be borne in mind in order to know whether after unsatisfactory roentgenograms the leg should be rotated more inwards or outwards for the next exposure

Form of the Medial Malleolus Normally the articular surface of the medial malleolus forms a varus angle of 20° to 30° with the long axis of the tibial shaft Following a bimalleolar fracture with lateral displacement this angle may decrease to 0° as in figure 2670 or become negative, i e, the medial malleolus deviates in the sense of valgus of varying degree (fig 2675) It may come to lie transversely (horizontally), i e, reach a valgus of 90° (figs 2704, 2716) In supination-adduction fractures the varus position of the medial malleolus is increased (figs 2625 2635) As long as the normal angle of 20° to 30° has not been restored there is still a lateral or medial subluxation (figs 2676, 2723 a, 2724 a) and arthrotic changes will ensue (fig 2677) Whether the angle between the articular surface of the medial malleolus and the tibial shaft should be 20° or 30° after reduction, can only be determined from a comparison roentgenogram of the uninjured side One should also be aware that the medial malleolus projects far medially (fig 2627)

Form of the Lateral Malleolus The lateral malleolus has a concave contour laterally at the level of the ankle joint This concavity appears more or less pronounced depending on the degree of rotation of the leg during the roentgen examination (figs 2627—2629) This concavity disappears in ankle fractures and epiphyseal displacements caused by supination-adduction In these cases the lateral malleolus is straight (fig 2567) or shows a convex lateral contour

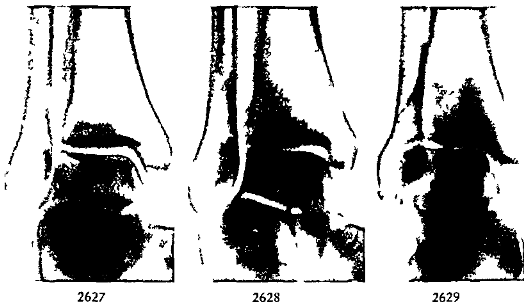


Fig 2627 —Anteroposterior roentgenogram of the ankle joint at internal rotation of about 20° The leg is rotated so that the lateral margin of the foot becomes vertical The sole of the foot is propped with a sand bag The joint space between the medial malleolus and the talus is shown distinctly The lateral malleolus touches the talus Whether or not the joint space is closed can be determined only in this position The fibula shows a slight concavity in the region of the ankle joint The joint space of the medial malleolus forms an angle of 25° with the long axis of the tibia

Fig 2628 —Anterior roentgenogram of the ankle joint taken with the leg in inward rotation of 30° to 35° The lateral edge of the foot is then rotated 10° to 15° inward The joint space between talus and lateral malleolus is now clearly shown while the medial joint space is indistinct The space between the shaft of the tibia and the shaft of the fibula is wider than in fig 2627

Fig 2629 —Anteroposterior roentgenogram of the ankle joint at 30° external rotation of the leg The shadows of the medial and to a greater degree the lateral malleolus overlap with that of the talus so that the malleolar joint spaces can no longer be judged Due to external rotation there is no space between the tibia and the fibula

(fig 2686 a) Reduction is complete only when the lateral concavity has been restored (fig 2567 a) and the angle between the articular surface of the medial malleolus and the long axis of the tibia is 20°—30° (fig 2686 c) Severe growth disturbance follows if these conditions are not considered (figs 2571—2573)

Lateral Roentgenogram of the Ankle Joint Also, for the lateral roentgenogram, the leg should be rotated internally through about 20° The lateral margin of the foot is laid on the cassette and the forefoot is propped by a small sandbag A sandbag is also placed under the front of the knee in order to avoid internal rotation of the foot in relation to the crus In this position the medial

and the lateral margins of the trochlea tali coincide in the roentgenogram and appear as a curve running parallel to the distal articular surface of the tibia (fig 2630) If the lateral margin of the foot is not supported, the leg is rotated less inwards and the margins of the trochlea tali cross and form a figure-eight Tibia and talus no longer appear congruous Moreover the talus appears shorter (fig 2630) The more the leg is rotated inwards, if too big a sandbag is used,



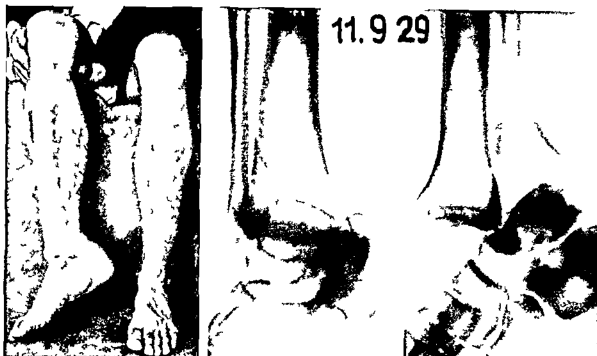
FIG 2630—Proper lateral roentgenogram of the ankle joint The whole joint space can be seen The contours of the tibia and the talus are congruous The lower leg is rotated internally through 20° Sandbags are placed under the front of the knee and under the forefoot

FIG 2631—The trochlea tali shows a figure eight if the lateral margin of the foot lies flat on the support The joint space can no longer be seen completely and bony avulsions from the posterior margin of the tibia are not shown properly The talus appears shorter than in fig 2630

FIG 2632—Lateral roentgenogram of the ankle joint at 30° internal rotation Trochlea tali and articular surface of the tibia overlap and the joint space cannot be judged well The fibular shaft appears more anterior than usual The talus appears still shorter than in fig 2631

the more pronounced is the incongruency of the contours of the ankle joint, and the shorter the talus appears (fig 2632) The degree of internal or external rotation of the leg can also be determined from the position of the fibula in relation to the tibia At external rotation the tibia shaft lies ventral to the fibula (fig 2631) and at maximum internal rotation the shafts of the fibula and tibia coincide (fig 2632)

Diagnosis of the Ankle Fractures If somebody says he has slipped and fell, then felt severe pain in the ankle joint and could only walk with pain or not at all, one should think of an ankle fracture Diagnosis is especially easy if marked change of the external shape, e g, valgus and external rotation (fig 2633) or varus (fig 2635) is present Moreover there is marked swelling and pain on pressure Excoriations and pressure sores are signs of direct force Blisters occur only after severe displacement on the second or third day



2633 September 11 1929 2634

Fig 2633 —External rotation of the foot and posterior dislocation The heel is displaced far backwards and the medial malleolus projects markedly The skin over the tip of the malleolus is anemic from tension and shows a dark spot a sign of beginning skin necrosis The forefoot appears shortened

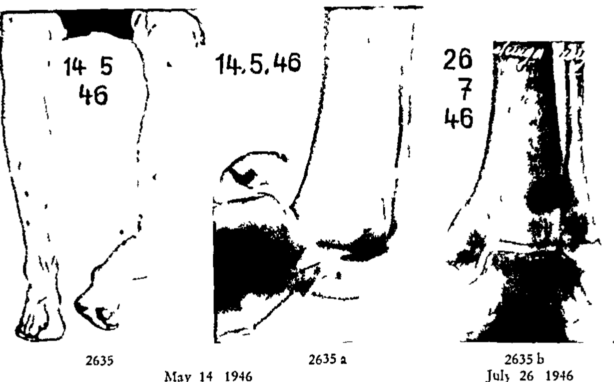
Fig 2634 —Roentgenogram of fig 2633 Marked external rotation and posterior displacement of the foot Torsion fracture of the lateral malleolus at the level of the ankle joint The medial malleolus is intact Stage 4 of supination external rotation fracture according to Lauge Hansen Sustained by an 18 year old goldsmith apprentice who was hit and thrown aside by a falling machine He fell to the left and backward while his foot was fixed on the floor Reduction under local anesthesia was easy Application of an unpadded lower leg cast which was split immediately One week later lower leg walking cast for another 13 week



2634 a March 26 1930 2634 b February 16 1937

Fig 2634 a—Same case $6^{1}/_{2}$ months later Bony union in good position Satisfactory mineralization

Fig 2634 b—Same case $7^{1}/_{2}$ years later Good position in both planes Slight marginal lipping at anterior and posterior tibial margin Toes and subtalar joint normal Dorsi flexion of ankle joint limited by 10^{0} plantarflexion normal Can walk normally Asymptomatic

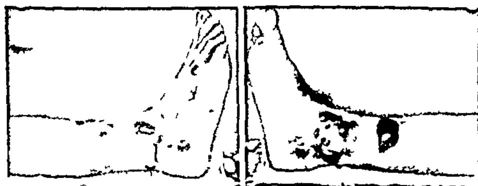


2635 2635 a 2635 b
May 14 1946 July 26 1946

Fig 2635 —Severe varus at the left supramalleolar region without rotation of the foot Sustained by a 59 year old coachman who slipped and fell to his side while loading barrels

Fig 2635 a —The lateral malleolus is torn off just above the level of the ankle joint the medial malleolus is sheared off Complete inward dislocation of the foot Reduction under local anesthesia was easy Unpadded lower leg cast which was split immediately throughout its full length Nine days later lower leg walking cast for an additional 11 weeks

Fig 2635 b —Same case 12 weeks later Bony union in good position Normal concavity of the lateral contour of the fibula De mineralization Patient resumed his work six months after the accident Subtalar joint limited 50/ ankle joint 85° to 102°



2635
Severe blisters in a malleolar fracture with severe displacement Arrived at hospital as late as three days after the accident

(fig 2636) In slight displacement the ankle joint should be tested for firmness and for impingement of the talus against the medial malleolus The roentgenogram taken under local anesthesia shows all details Only a roentgenogram taken "under strain" shows the extent of the original displacement (figs 2637 to 2640)



2637 September 21 1933 2638, September 21 1933

FIG 2637—Avulsion of the medial malleolus Torsion fracture of the fibula proximal to the middle with long torsion wedge Slight subluxation of ankle joint Sustained by a 25 year old scaffolder who jumped from a high ladder Marked swelling and distinct impingement of the talus against the base of the medial malleolus

FIG 2638—Same case in forced abduction under local anesthesia Only now one can recognize the full severity of the injury Wide gaping of the tibiofibular space a sign of rupture of the anterior and posterior tibiofibular ligament and of the interosseous membrane The posterior margin of the tibia has not been sheared off The medial malleolus is connected with the talus Stage 4 of the pronation external rotation fracture according to Lauge Hansen Reduced under local anesthesia Lower leg cast which is split immediately Ten days later lower leg walking cast for a further 15 weeks

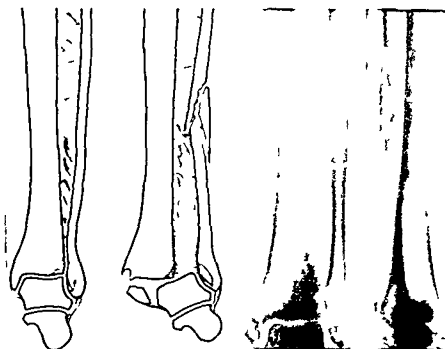
Concomitant Injuries In rare cases of the complete anterior or posterior dislocations (figs 2789—2792) *circulatory disturbances* result from pressure on the arteries *Nerve injuries* are very rare Projecting fragments which bulge out and stretch the skin may lead to necrosis of the skin and infection of the joint (Vol I/figs 19, 20 figs 2633, 2634)

Early complications may consist in circulatory damage caused by pressure on vessels, skin necrosis caused by delay in reduction of fractures with considerable tightening of the skin and re-displacement

Late complications may occur as late re-displacement with subsequent painful arthrosis and limitation of motion, persistent swelling and non-union of the medial or both malleoli

Avoidance of the Early Complications Circulatory disturbance from pressure on vessels and skin can be avoided by early reduction Re-displacement can be avoided by closing the cast in time and lengthening it up to the midthigh

Avoidance of the Late Complications Re displacement of the fragments after removal of the cast, and subsequent arthrosis and edema can be avoided by accurate reduction and sufficiently long immobilization Non-union of the medial malleolus occurs only when an obstacle to reduction is not removed by early operation



2639, October 17 1933 2640 January 22 1934

Fig 2639—Sketch re fig 2638 showing the extent of ligamentous lesion (disruption of malleolar fork)

Fig 2640—Same case four months later on removal of the walking cast Malleolar socket closed Bony union of the fractures The articular surface of the medial malleolus forms an angle of only 15° instead of 30° with the tibial shaft Fracture space of medial malleolus still visible Ossification of the interesseous ligament Normal range of motion of all joints seven months after the accident

Questions We Should Ask Ourselves in Order to Avoid Failures at the Examination and Recognition of Ankle Fractures

1 Have I examined the patient for the presence of shock?
2 Have I noted the color and expression of the patient s face (pale, flushed, covered with sweat, expression of pain)?
3 Have I asked how the accident happened?
4 Have I looked for angulation and rotation before the patient is stripped of clothes?
5 Have I asked the patient s name, age, occupation body height and weight, and address?

(fig 2636) In slight displacement the ankle joint should be tested for firmness and for impingement of the talus against the medial malleolus The roentgeno gram taken under local anesthesia shows all details Only a roentgenogram taken "under strain' shows the extent of the original displacement (figs 2637 to 2640)



2637 September 21 1933 2638 September 21 1933

Fig 2637—Avulsion of the medial malleolus Torsion fracture of the fibula proximal to the middle with long torsion wedge Slight subluxation of ankle joint Sustained by a 25 year old scaffolder who jumped from a high ladder Marked swelling and distinct impingement of the talus against the base of the medial malleolus

Fig 2638—Same case in forced abduction under local anesthesia Only now one can recognize the full severity of the injury Wide gaping of the tibiofibular space a sign of rupture of the anterior and posterior tibiofibular ligament and of the interosseous membrane The posterior margin of the tibia has not been sheared off The medial malleolus is connected with the talus Stage 4 of the pronation external rotation fracture according to Lauge Hansen Reduced under local anesthesia Lower leg cast which is split immediately Ten days later lower leg walking cast for a further 15 weeks

Concomitant Injuries In rare cases of the complete anterior or posterior dislocations (figs 2789—2792) *circulatory disturbances* result from pressure on the arteries *Nerve injuries* are very rare Projecting fragments which bulge out and stretch the skin may lead to necrosis of the skin and infection of the joint (Vol I/figs 19, 20, figs 2633, 2634)

Early complications may consist in circulatory damage caused by pressure on vessels, skin necrosis caused by delay in reduction of fractures with consider able tightening of the skin, and re displacement

Late complications may occur as late re-displacement with subsequent painful arthrosis and limitation of motion, persistent swelling, and non-union of the medial or both malleoli

27 Have roentgenograms been repeated until the articular surfaces of the tibia and trochlea tali appear congruous (fig 2630)?
28 Have I noted the varying width of the tibio fibular space in different degrees of rotation (figs 2630—2632)?

TREATMENT OF THE PRONATION-ABDUCTION FRACTURES OF THE MALLEOLI

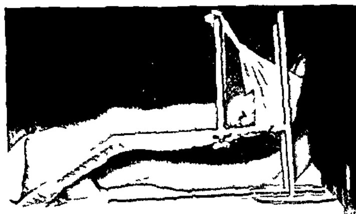
Although they represent a small group (only 6% in Lauge-Hansen cases), among the different types of ankle fractures, I will describe the treatment of the pronation-abduction fractures first, since reduction and immobilization is achieved the most easily

For reduction and treatment of ankle fractures the following in general are required

1 A table as shown in figure 2175
2 A stand with two steps or a stool to put the uninjured foot on as in figure 2175
3 Local anesthesia (see Vol I/p 118 and fig 152)
4 A small table for the equipment for local anesthesia
5 A second small table to place the items quoted under 6—13
6 A rubber apron
7 Rubber gloves
8 Bandage scissors
9 A 6 to 7 mm thick, 100 cm long hemp cord or
10 an adequate strip of corrugated rubber
11 Skin adhesive solution (Mastisol)
12 Swab sticks (Vol I/fig 152)
13 Flannel strips, 5 by 50 cm (fig 2175), incised for 1 cm at one edge a distances of 5 cm
14 Satisfactory anteroposterior and lateral roentgenograms, both taken at 15° to 20° internal rotation
15 An ordinary ruler and a protractor, both transparent (Vol I/figs 91—94), to measure the roentgenograms
16 Three 18 thread (9/9 per cm = 6/5 per ¼') plaster bandages, 15 cm wide and 5 M long weighing 400 Gm (see Vol I/pp 115—117) for a lower leg bed cast, which is split immediately, or
17 Five 18 thread plaster bandages for a lower leg walking cast with walking heel (fig 2417) or
18 Eight 18 thread plaster bandages for a full leg bed cast, which is split immediately
19 A roll of foam rubber or cellulose 5 cm in diameter and 20 cm long
20 A roll of foam rubber or cellulose, 8 cm in diameter and 20 cm long
21 A bed with firm support (boards throughout the full length and width of the bed (Vol I/figs 99, 100, figs 2374, 2375)
22 A well bandaged Braun splint (figs 111, 2374)
23 A supplementary U support for the lower leg splint (figs 109 b, 2374, 2375)

6 Has the patient been stripped of his clothes in a warm room without producing pain?
7 Have I, with the patient stripped, determined and recorded the external shape of the ankle joint and the foot (swelling, valgus and external rotation (fig 2633), varus (fig 2635), apparent shortening or lengthening of the forefoot caused by posterior or anterior dislocation, fragments projecting underneath the skin in comparison with that of the well leg (figs 2633 2635)?
8 Have I observed the color of the foot (paleness of the whole foot or only over the projecting fragment, cyanosis, or normal color)?
9 Have I looked for excoriations, bruises, or blisters?
10 Have I examined with my hand the skin temperature of the injured foot and compared it with the sound foot?
11 Have I checked the dorsalis pedis and posterior tibial pulses of both feet?
12 Have I tested the patellar tendon reflex on the sound side?
13 Have I checked both pupils as to their size and shape as well as to their reactions to light and convergence
14 Have I tested active motion of all joints in both lower extremities, starting *with the toes and ending with the hip*?
15 Have I measured and recorded limitations of motion in degrees and compared them with the sound limb?
16 Have I gently palpated the sites of greatest tenderness in order to locate the fracture lines?
17 Have I tested the firmness of the joint and examined the possibility of impinging the talus against the medial malleolus, without causing considerable pain?
18 Have I, after the quickly performed clinical examination, anesthetized the joint locally to abolish pain and abate shock?
19 Have I taken roentgenograms of the anesthetized joint "under stress" to show the original displacement (figs 2637—2640)?
20 Have I refrained from excessively displacing the fragments in gross injuries?
21 Has the leg been internally rotated through 15° to 20° for the anteroposterior roentgenogram so that the lateral margin of the foot is vertical (fig 2627)?
22 Has the lateral roentgenogram been taken at 25° to 35° internal rotation to show the joint space between talus and lateral malleolus?
23 Have I *noted the distance between the tibial and the fibular shafts in the* anteroposterior roentgenogram (figs 2627—2629)?
24 Have I measured the post-reduction angle between the articular surface of the medial malleolus and the tibial shaft in the anteroposterior roentgenogram?
25 Have I noted the disappearance of the concave outline at the lateral side of the lateral malleolus in supination adduction fractures and epiphyseal displacements (sketch of fig 2567)?
26 Has a small sandbag been placed under the outer side of the forefoot and under the front of the knee for the lateral roentgenogram?

Positioning the Patient and the Lower Leg If local anesthesia is used the patient sits at the edge of the table the legs flexed at the knees and hanging down If general anesthesia is used the patient lies on the table with his lower legs hanging down The fractured foot rests on the surgeon's knees (fig 2644) If the lower leg is long the thigh no longer rests on the table and the knee moves from side to side during reduction and application of the plaster bandages If the table is not adjustable to elevate or lower the patient according to need, a roll of 8 to 15 cm in diameter is placed under the thigh proximal to the knee to support the leg The uninjured foot rests on a stool (which is not shown in figs 2644—2650) If the sound foot hangs free, the muscles of



2641 December 9 1933

Positioning a severe injury of the ankle region without displacement by suspending the forefoot in a triangular bandage

the injured leg are contracted involuntarily and reduction is impeded Reflex muscle tension is abolished by the local anesthetic, and flexion of the knee joint at a right angle fully relaxes the gastrocnemius (see Vol I/figs 1—6) Reduction of posterior dislocations with the knee extended, as was generally done in former times and still has some advocates, is possible only with great force

Reduction Reduction of pronation abduction fractures is as a rule, easy, since there is angulation only in the frontal plane with a valgus of varying degree and no rotation For reduction of fractures of the right ankle joint the surgeon s right hand grasps the medial side of the lower leg two fingerbreaths above the ankle joint, his left hand grasps the region of the lateral malleolus so that two fingers lie above and two fingers lie below the ankle joint While the right hand holds the lower leg, the left hand presses the lateral malleolus, the displaced talus, and the whole foot medially (fig 2647) Reduction is achieved, as a rule, without considerable force Overcorrection occurs only if force is used The heel remains in the mid position between pronation and supination, and the front part of the foot is in mid-position and not in supination To get this position, the patient supports the head of the fifth metatarsal on the operator s knee, so as to raise the lateral and depress the medial margin of the foot

24 A wooden box 25 × 30 × 40 cm or 10 × 40 cm to prop the sound foot against (figs 118, 2374, 2375)
25 A radiant heat cradle (baker)
26 In cool weather, a hot water bottle (Vol I/fig 157, Vol II/fig 1604 d)

Time of Reduction Reduction is easy if performed within the first few hours following the accident If reduction is delayed there will develop considerable pain, severe swelling, and blisters in some cases (fig 2636) If the skin is considerably tightened over a projecting bone and is anemic or if the foot is pale and cold due to pressure on the arteries, reduction must be carried out immediately to avoid local necrosis of the skin and gangrene of the foot In fractures without displacement the application of the cast may in some cases be delayed a few days until the swelling has subsided The leg meanwhile is placed on a Braun splint (fig 2641), a gutter splint, or a pillow, and wet compresses are applied, though the least pain is felt, also by patients with fractures without displacement, if a split bed cast has been applied

Checking the Material Listed on Page 1917 While the roentgenograms are developed all items necessary for reduction, immobilization, and positioning of the patient are checked against the list

Heating the Bed The bed is, at the same time, heated with a heat cradle

Preparation of the Skin for Local Anesthesia The skin is painted at the site of injection with a single dab of iodine or another antiseptic solution One should not scrub the skin of the ankle with benzene and should not apply several coats of iodine as this might irritate the skin and cause blisters and eczema with possible infection of the hematoma After one coat of iodine irritation of the skin is rare Dirty skin should be gently washed with warm water and soap, without causing pain

Preparation of the Skin for Application of an Unpadded Plaster Cast The skin of the lower leg is not shaved or greased before the plaster is applied Benzene or alcohol are not used The plaster attaches itself uniformly to the hairs and holds more firmly No pain is produced because the pull is exerted equally on all hairs and not felt If the skin is greased, the cast loses its grip and moreover, the grease destroys the plaster

Local Anesthesia If the ankle joint has not yet been anesthetized locally for roentgen examination this should be done now as described on page 1908 The injection points are covered with Mastisol and 2×2 cm sterile swabs Of more than 12,000 ankle fractures we have reduced 90% under local anesthesia

Study of the Roentgenograms When the roentgenograms have been finished, they are carefully studied before the viewing box regarding type and form of fracture, and extent of displacement in order to plan the course of treatment The roentgenograms are then displayed before the window or the viewing box for ready reference during reduction and application of the plaster cast

Dispersal of the Swelling and Hematoma Following local or general anesthesia the swelling is dispersed by firm pressure of both hands until both malleoli and the sinus tarsi become evident This often requires 5 to 10 minutes

should begin below the knee and proceed downwards evenly, leaving two or three finger breadths between the upper edges of each turn (fig 2646) The cast should be of uniform strength throughout After application of the first circular plaster bandage the notched margin of the flannel strip is turned down Then the second circular plaster bandage is wound on in the same way as before Then the distal end of the plaster splint is swung from the extensor side of the toes to the flexor side so that the cast reaches as far as the tips of the toes At the first and fifth toe the cast should reach laterally to the toenail If this is not the case the toe-plate will soon break The toe-plate should lie in line with the sole of the foot and not be curved as shown in figures 2653 and 2655 as this would impede plantarflexion of the toes

As a fresh lateral subluxation might have been produced by the tension of the pronators or abductors (Vol I/figs 23, 24) firm pressure is again exerted on the medial side of the lower leg and the lateral side of the lateral malleolus The reduced fracture is held fast with both hands until the plaster has set If pressure is relaxed too soon the foot may become re-displaced

Supporting the Cast on Sponge Rubber or Cellulose Rolls As soon as the plaster cast has hardened, the patient lies down or the lower leg is placed horizontally in the already recumbent patient The 5 cm thick sponge rubber or cellulose roll is placed under the Achilles tendon (Vol II/fig 1634) and the 8 cm thick roll is placed under the knee to avoid pressure on the heel and subsequent decubitus ulcer

Roentgen Check Anteroposterior and lateral roentgenograms are taken at 15° to 20° internal rotation as in figures 2627 and 2630 They are viewed according to the rules given on pages 1909—1911

Application of a New Plaster Cast if Position of the Fragments is Unsatisfactory If the roentgenograms show still the slightest displacement the cast must be removed immediately, the fracture must be re-reduced, a new plaster cast applied, and new roentgenograms taken This procedure is repeated until no trace of displacement remains Even if there is only 1 mm displacement of the talus the joint is incongruent and the patient will suffer lasting disability because the surfaces of the articular cartilage become rubbed away and produce arthrotic changes in the course of years

Trimming the Cast As soon as the roentgenograms show good position the edges of the cast are trimmed in front of the toes and behind the knees On the sole of the foot it should extend as far as the tips of the toes, and at the back of the foot to the clefts between the toes If it is as long as shown in figures 2653 and 2655 the toes cannot move If it is shorter, e g 1 cm behind the web of the toes, edema occurs If the edge is then cut further back, the edema will increase and decubital ulcers may develop Even erysipelas may occur

Dispersing the Edema with Sponge Rubber If edema has developed it is pressed away with sponge rubber Then the plaster cast is lengthened to the webs of the toes At the back of the knee the cast should be cut out enough to allow comfortable flexion to the right angle (fig 2652) The upper end of the fibula should be covered by the cast If the cast ends distal to the head of the fibula, pressure of the edge of the cast may cause paralysis of the

Avoidance of Traumatic Flat foot and Position of the Foot in the Frontal Plane Most text-books advise that the forefoot should be placed in marked supination or varus position (fig 2661) so as to prevent the later occurrence of flat foot But placing of the foot in this position promotes flat-foot and does not prevent it Flat-foot is a supination (fig 2519 b) and not a pronation contracture (fig 2519 c) of the forefoot It can therefore only be prevented by slightly pronating the forefoot, at mid position of the heel in order to place the heads of the first and fifth metatarsals on the same level In malleolar fractures the pronation and abduction occur at the ankle joint, where normally only dorsal and plantar flexion are possible Rotary movements of the normal foot round its long axis i e, pronation and supination, occur in the joints below and in front of the talus and in the tarsal joints Lateral subluxation of the talus can never be corrected by rotating the forefoot in supination but only by properly pushing the whole foot toward the medial side

Position of the Foot, in Relation to the Lower Leg, in the Sagittal Plane Since the trochlea tali is wider in front than at the back, dorsiflexion of the foot presses the malleoli apart In plantarflexion the malleolar fork is closed by active muscle action Immobilization of ankle fractures should therefore be carried out at a 5° to 10° plantarflexion The sole of the foot should form an angle of 95° to 100° with the long axis of the lower leg Immobilization in dorsiflexion would drive the malleoli apart If the fracture healed in this position the malleolar socket would be too wide and the joint would be loose Figure 2657 shows incomplete and figures 2658 and 2672—2674 show complete reduction of pronation-abduction fractures

Immobilization An unpadded plaster cast is applied to maintain the position of the reduced fragments

Placing a Thick Hemp Cord for Splitting the Cast One end of the 6 to 7 mm thick, 100 cm long hemp cord is knotted This knot is placed on the plantar side between the second and the third toe The hemp cord is then guided over the dorsum of the foot, the anterior side of the lower leg (just lateral to the tibial crest), over the middle of patella and thigh It enables us to split the cast without touching the skin with the plaster knife

Placing the Flannel Strip Distal to the knee joint 3 to 4 longitudinal strokes of skin adherent are applied and the 5×50 cm incised flannel strip is glued on

Application of the Lower Leg Bed Cast A plaster splint three spans or 70 to 75 cm long, is made of one plaster bandage by folding the plaster bandage on a glass plate The plaster splint is applied to the back of the lower leg The upper margin of the splint should not reach beyond the flannel strip and *not* touch the skin to avoid pressure The splint is then guided along the back of the lower leg and the sole of the foot beyond the tips of the toes and turned back onto the extensor side of the toes and the back of the foot The plaster splint should be put on very wet It is cut at each side of the heel (fig 2645) to avoid folds Both edges of the splint are smoothed down on the lower leg and on the foot so that not the slightest ridge is formed The splint is fastened with one circular plaster bandage In winding on this bandage, one





2646 2647

Fig 2646 —The two corners of the notched plaster splint are smoothed over one another

Fig 2647 —Subluxation outward is reduced by holding one hand just above the medial malleolus and pressing firmly with the other hand against the lateral malleolus (not the heel) so pressing the talus against the medial malleolus This pressure is exterted until the plaster has set





2648 2649

Fig 2648 —Finished plaster cast

Fig 2649 —Walking stirrup applied in the axis of the lower leg At present we use the stirrup shown in fig 2417



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Fig 2642 — Folding a plaster bandage to make a splint on a glass plate The splint is smoothed by hand

Fig 2643 – Finished plaster splint



2644

February 4 1928



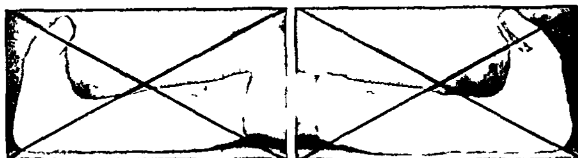
2645

Fig 2644 — The patient sits on a table His knee is flexed his foot flexed at a right angle rests on the surgeon s knee The stool for the support of the sound foot is omitted from the picture A very wet plaster splint 15×70 to 80 cm is applied from the hollow of the knee over the heel beyond the toes after having glued a 5 cm wide flannel strip to the skin below the knee with skin adherent

Fig 2645 – The posterior plaster splint is incised at the heel and fastened on with a plaster bandage

peroneal nerve Finally a finger should be passed between the upper and lower edge of the cast and the skin to avoid pressure from a sharp edge

Cleaning the Toes When the cast has been trimmed the toes should be carefully cleaned before the patient leaves the plaster room so that circulation can be readily checked If washing the toes is delayed for some hours it is, as a rule, very painful because the hardened plaster particles can be removed from the skin only with difficulty

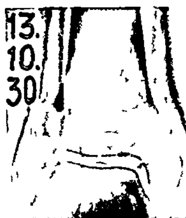


2655 January 4 1928

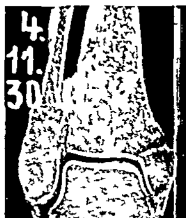
FIG 2655 Poorly applied cast Extreme calcaneus position and maximum dorsiflexion of the toes



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2658

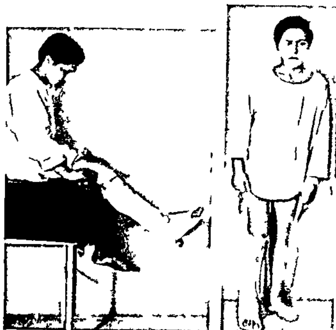
FIG 2656—*Open* pronation abduction fracture Stage 3 with avulsion fracture of the medial malleolus and flexion fracture of the lateral malleolus 3 cm proximal to the ankle joint Sustained by *a 56 year old blacksmith s apprentice who was struck by* an iron bar at the lateral side of the right lower leg Treatment consisted of wound excision under local anesthesia reduction and application of a lower leg cast which was immediately split and windowed The wound was kept without a dressing On the 18th day after the accident a lower leg walking cast was applied

FIG 2657—Same case after application of the walking cast There is still slight subluxation and a 10° valgus of the lateral malleolus The articular surface of the medial malleolus forms an angle of 10° instead of 20° with the long axis of the tibia The plaster was therefore removed and the fracture again reduced

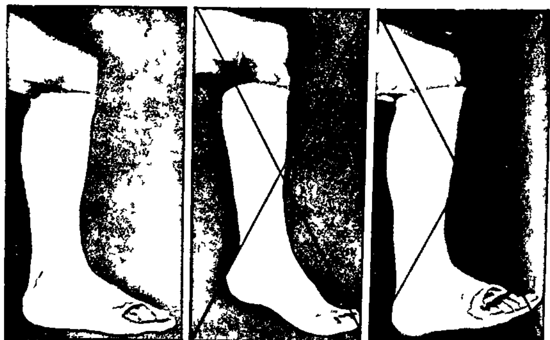
FIG 2658—Same case *frontal section through the fracture dislocation* The patient suddenly died from coronary thrombosis on the 41st day after the accident The position of the fragments is good The fibula is straight The angle between the articular surface of the medial malleolus and the long axis of the tibia is 20°

Splitting the Cast If the plaster cast is applied within the first two days after the accident it must be split immediately i e, before the patient leaves the plaster room The splitting is carried out along the laid-in hemp cord throughout the full length of the cast, i e, every single thread of the bandages must be cut, in order to avoid circulatory disturbances and severe pain

Using a Vacuum Cleaner If plaster particles have dropped into the cast they can be removed with a swab stick or pincers, or better still with a vacuum cleaner



2650 February 4 1928 2651



2652 2653 2654

FIG 2650—The walking stirrup is fixed by a plaster bandage

FIG 2651—On the finished cast the sketch of the pre reduction roentgenogram and the dates of accident reduction and removal of the cast are marked (see fig 2416)

FIG 2652—Properly applied plaster cast The upper margin lies anteriorly at the tibial tubercle posteriorly at the insertion of the biceps tendon to allow comfortable flexion of the knee to a right angle The fibular head is covered by the cast 10° plantar flexion of the ankle joint Toes well supported at the flexor side but free up to the web on the extensor side

FIG 2653—Faulty plaster cast It is too short proximally so that soft tissue of the calf and the fibular head reach beyond its margin Equinus position The cast is too long over the toes which are thereby hindered at extension

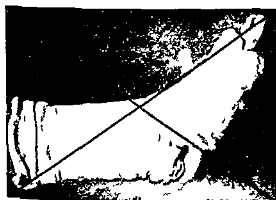
FIG 2654—Faulty plaster cast It is too long proximally so that flexion of the knee is hindered Calcaneus position The back of the foot is not completely covered by the cast This may cause edema and marginal decubital ulcers



2662 February 4 1928 2663

Fig 2662 —Unpadded cast removed and compared with a thickly padded cast which was so heavy that the patient could not walk with it

Fig 2663 —Unpadded plaster cast and the walking stirrup with its plaster bandage taken apart





2664 January 6 1931 2665 February 4 1929

Figs 2664 2665 —Poor plaster casts being too short proximally and distally and applied in equinus position

Attaching a Supplementary U-support A supplementary U-support is attached over the middle of the lower leg (fig 2374)

Positioning the Patient in Bed The patient is lifted with the splint into the pre-warmed bed which has boards under the mattresses A wooden box serves as a prop for the sound foot

Exercises in Bed The toes must be actively extended beginning the first day Should this later become impossible, paralysis of the peroneal nerve has developed Then, the cast must be more widely spread at the fibular head

Marking the Cast The pre-reduction roentgenograms are sketched in full size over the fracture site The days of the accident, of the reduction, of the application of the plaster cast and of the planned removal, the date and hour of the next roentgen check, and the name of the surgeon are inscribed on the cast In order to find out easily and quickly the period of the planned immobilization, the number of weeks is also marked on the cast beside the dates (figs 2415, 2416)



2659 September 28 1928 2660 2661 September 17 1928

Figs 2659—2661 —Poorly applied plaster casts too short proximally and distally equinus position internal rotation and supination

Checking the Roentgenograms, the Cast the Roentgen Sketch, and the Inscription If a junior resident physician has applied the cast, it should be examined by a senior He checks the position in the last roentgenograms in both planes, that the cast has been applied properly and not in position of equinus or calcaneus, that the cast is trimmed correctly at the extensor side of the toes, that the toes have been cleaned well and that the period of immobilization has been planned correctly, i e, not too long and above all not too short As proof of the examination he signs the cast The signature should never be given in blanco i e, without accurately viewing the roentgenograms or before the cast has been fully inscribed In this way the young doctors can soon learn the important points

Paper Bandage To avoid soiling the linen with the inscription written with indelible pencil the marking is covered for a few hours with a paper bandage

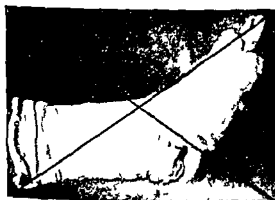
Placing the Leg on a Braun Splint The leg is supported on a Braun splint A hole is drilled through the toe plate between the second and third toe A small bandage serves to suspend the foot on the transverse bar of the Braun splint to avoid external or internal rotation



2662 February 4 1928 2663

Fig 2662 —Unpadded cast removed and compared with a thickly padded cast which was so heavy that the patient could not walk with it

Fig 2663 —Unpadded plaster cast and the walking stirrup with its plaster bandage taken apart





2664 January 6 1931 2665 February 4 1929

Figs 2664, 2665 —Poor plaster casts being too short proximally and distally and applied in equinus position

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In addition, a piece of sponge rubber is placed between the toes and the toe plate

Further Spreading of the Cast in Case of Pain or Severe Swelling If pain is felt on the first or second day and the skin bulges where the cast is split, it must be further spread especially at the ankle joint

Closing the Split Plaster Cast When after 2—3 days the swelling begins to subside the edges of the cast should be pulled together to avoid re-displacement in a cast which has become too wide

Application of the Lower Leg Walking Cast After 8 to 10 days when the swelling of the leg has subsided the split temporary cast is removed, and a lower leg walking cast is applied in the same way as described on page 1920 Three circular plaster bandages are required *and four if the patient weighs* more than 80 Kg Should swelling still be present before application of the cast it must be completely pressed away, especially around the ankles

Roentgen Check in the Lower Leg Walking Cast After application of the lower leg walking cast new anteroposterior and lateral roentgenograms should be made, 15° to 20° internal rotation

Application of a New Lower Leg Walking Cast if the Position of the Fragments is Unsatisfactory If the roentgenograms show the slightest displacement the cast must be removed at once, the displacement must be corrected, a new walking cast is applied, and new roentgenograms taken This must be repeated until all displacements have been completely corrected

Application of the Walking Iron If the position of the fragments is satisfactory a walking iron is applied We no longer use the walking iron shown in Vol I/fig 143 since it must be removed for lateral roentgenograms At present we use a walking heel with four thick vertical wires, designed by Zehetgruber (fig 2417) It is applied in such a way that its vertical wires do not cover the malleoli in the lateral picture The stirrup does not relieve the fracture from weight-bearing, but protects the sole of the cast

Trimming the walking cast cleaning the toes marking and checking the cast is carried out as described on pages 1921—1926

Exercises in the Walking Cast When after a few hours the plaster cast has hardened the patient should begin to walk with the aid of a cane the first few days and then without In the first week he should walk at least 1 km each day, increasing this by 1 km each week, *if this causes no pain* Knee and toes should be actively moved from the first day on Of the muscles in the lower leg only four are completely immobilized by the short leg walking cast, namely, the tibialis anterior and posterior, and the peronneus longus and brevis Even these tighten when the other muscles move even though they cannot shorten and thus they do not atrophy If the patient walks conscientiously the circulation of the whole leg including the immobilized muscles is good The possibility of walking affects not only the leg but the whole body and the morale As evidence of good circulation if there is swelling of the toes it disappears in a few days People who lead sedentary lives, e g, doctors or merchants can return to their occupation in a few days As the patient is again quickly on his feet, local or general complications such as venous thrombosis or pulmonary and cardiac complications which are so

often seen in patients who have to lie in bed do not develop The patient has no feeling of illness Appetite and sleep are normal Patients who have not resumed their work take part in group exercises

If varicose veins or chronic ulcers of the leg are present, these tend to subside or actually heal under the cast

Roentgen Check One week later new anteroposterior and lateral roentgenograms must be taken in internal rotation of 15° to 20° (figs 2627 and 2630) The new type walking heel (fig 2417) need not be removed for this Subsequently roentgenograms are taken in both planes every other week Anteroposterior and lateral roentgenograms should also be taken on removal of the cast and on discharge from treatment If the pain does not disappear by one week after removal of the cast new roentgenograms in both planes should be made as redisplacement may occur if immobilization has been too short

Change of the Cast If the patient states the cast is loose in the morning it should be changed If the roentgenograms show any displacement the cast must be replaced at once Following each change of the cast new roentgenograms in both planes at 20° internal rotation must be made

Period of Immobilization Exact reduction and the best plaster cast will fail to yield a good result, if immobilization is interrupted before bones and ligaments have firmly united

If there has been no displacement the cast remains for six weeks In displacement of 2 to 3 mm (Vol I/figs 85—88) it should remain for eight weeks, in displacement of 5 to 10 mm 10 to 12 weeks In complete rupture of the tibio-fibular joint (figs 2637—2640) and in complete dislocations (figs 2703, 2704) immobilization must continue for 16 weeks Besides the extent of the displacement, the body weight must be considered when determining the duration of immobilization Some authors believe that torn ligaments cannot heal Figures 2637—2640, 2703—2706, 2731—2734 and hundreds of similar cases treated in our hospital prove that firm union in good position without looseness of the joint can be achieved by adequate immobilization even after complete rupture of all ligaments and the joint capsule

Figures 2675—2677 and 2747—2751 show consequences of poor reduction and too short immobilization The foot becomes displaced and even in youths severe arthrotic changes develop

The former opinion that immobilization stiffens the ankle joint is no longer tenable If immobilization is maintained long enough, i e, until firm union has been achieved and if adequate exercises are carried out, the joint mobility will, as a rule, become almost or completely free If, however the cast is removed too soon, motion of the joint will be limited because of redisplacement of the fragments Moreover, the patients are free from pain as long as they wear a properly applied unpadded walking cast and walking will be painless if the cast has been removed only after bony union in good position If the cast is removed sooner weight bearing is painful since the fracture site is still soft The fragments become displaced swelling occurs, and those painful contractures or limitation of motion develop which the surgeon has wished to avoid by early removal of the cast and premature

movements Displacement of the fragments causes arthrotic changes and limitation of motion as the incongruous surfaces of the articular cartilage grind on each other We must remember that immobilization that is 2 to 4 weeks too long will do no harm, but permanent disability may follow immobilization that is 2 weeks too short

Further Treatment following Removal of the Lower Leg Walking Cast If, following accurate reduction and adequate exercises, the cast is removed only after bony union has been achieved, the range of motion of the ankle joint is at least 50% of normal in elderly patients and in young patients up to 30 years of age it is often normal The skin is not atrophic, not swollen and not shiny, but shows normal folds and normal color The calf muscles are only slightly weaker than on the well side, and the roentgenograms show almost normal or completely normal mineralization The patients can walk free from pain without a bandage



2666 September 13 1935 2667

Figs 2666 2667 —Long torsion fracture of the lateral malleolus and subluxation of the talus 8 mm outward No gape of tibiofibular space Compare with fig 2610 c Stage 4 of the supination external rotation fracture according to Lauge Hansen

Case History I have seen an 85 year old woman who had sustained a fracture of both malleoli with dislocation of the talus by almost its full width She had conscientiously walked with her walking cast When the cast was removed twelve weeks after the accident she could at once move her ankle joint through almost its full range of motion

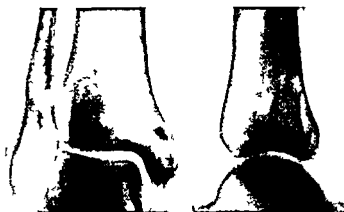
If considerable pain is felt after removal of the cast, although the patient had walked a good deal with the cast, it is a sign that the fracture has not yet completely united and a new plaster cast should be applied for a few more weeks If reduction was exact, the roentgenogram as a rule shows no periosteal callus at the ankle

Application of the Unna s Paste Boot If the fracture is firm an Unna s paste bandage is applied from the web of the toes up to the knee During the first few days walking is, as a rule, more difficult than in the walking cast and the ankle joint is tender especially on walking downward The Unna's paste bandage is changed one week later and then every 2 to 4 weeks if it is loose Young people wear it 3 to 6 weeks elderly people and those with varicose veins up to 6 months They can resume their work with it

Exercises After Removal of the Cast To mobilize the joint and to strengthen the muscles the patients are requested to exercise by repeated vigorous plantarflexion while sitting with the toes touching the floor After four to five weeks they should try to stand and to walk on tiptoe and later they should do deep knee bends, *if this causes no pain* Patients who have difficulty after prolonged walking should exercise with the mountain climbing apparatus (Vol I/figs 21, 22) Group exercises are performed in addition

Energetic massage and forceful passive movements are always harmful Massage is possible only when Unna's paste bandage is removed Then the very swelling appears that one has wished to avoid Passive movements irritate the joint and cause swelling The Unna's paste bandage promotes healing by preventing edema of the foot and lower leg

Use of the Arch Support Patients with a weak arch should be given an arch support if there has been an ankle fracture with severe displacement



2668 September 14 1937 2669

FIGS 2668 2669—Same case two years later Bony union in good position Had a walking cast for 10 weeks Resumed work four months after the accident Joint stable and almost freely mobile The site of the fracture is hardly detectable two years after the accident

It is preferably made from a plaster model The patient sits on the end of the table with the knee bent to a right angle and the foot hanging down A strong piece of cord with a knot at the end should be placed between the second and third toes and brought over the dorsum of the foot up to the leg A 30 cm long splint folded three times is applied to the sole of the foot and fastened with a circular plaster bandage 3 M long The heel is slightly supinated and the front of the foot pronated, so as to produce a well-marked longitudinal arch The transverse arch should also be moulded After a few minutes when the plaster has set it is opened along the cord and removed The cast is then filled with fluid plaster to form a model of the foot From this model the arch support can be made from duraluminium, bronze, plastic, or as suggested by Lange and Hohmann from celluloid supported by steel wires

The cases described in Vol I/pp 32, 33, 48, 49 and those depicted in figures 2747—2752 show how ankle fractures should *not* be treated The cause of previously described poor results of ankle fractures was always the

same, namely, inexact reduction and insufficient immobilization so that massage and passive movements could be started earlier Thereby the fragments were re-displaced even if they had been well reduced



2670 October 26 1935 2671



2672 January 15 1936 2673 March 4 1936 2674 April 25 1936

Figs 2670 2671 —Avulsion of the whole medial malleolus and flexion fracture of the fibula 6 cm above the ankle joint with a 3 cm long lateral bending wedge Avulsion of a 1 cm long piece of bone from the tibial ligamentous insertion Subluxation of 10 mm Os trigonum Sustained by a 56 year old unskilled worker who was hit by a collapsing pile of wood on the lateral side of the right lower leg The angle between the articular surface of the medial malleolus and the tibial shaft is only 5° Stage 3 of the pronation abduction fracture after Lauge Hansen Compare with fig 2611 b

Fig 2672 —Same case on removal of the cast Bony union of the fragments Fracture space at medial malleolus still clearly visible The joint is stable Demineralization especially near the epiphyseal line The angle between the articular surface of the medial malleolus and the long axis of the tibial shaft is 20°

Fig 2673 —Same case five months later Mineralization improved

Fig 2674 —Same case six months later Normal mineralization Osseous union of the fracture Ankle joint freely mobile

Questions We Should Ask Ourselves in Order to Avoid Failures When Treating Pronation-Abduction Fractures

1. Have I checked the material necessary for reduction and immobilization of ankle fractures as described on page 1917?
2. Have I checked the material for completeness and quality?
3. Has the patient's bed been warmed?
4. Have I performed reduction within the first few hours, if possible?



2675 August 10 1929 2676 October 27 1929 2677 September 12 1931

FIG 2675—Stage 4 of a pronation external rotation fracture after Lauge Hansen Avulsion of the medial malleolus and long torsion fracture of the fibula 4 to 8 cm above the ankle joint Disruption of the tibio fibular syndesmosis wide gaping of the syndesmotic space Seven months after the accident Compare with fig 2611 a Sustained by a 23 year old student who fell when skiing Treated elsewhere by plaster for eight weeks followed by massage passive movements and blue light

FIG 2676—Same case ten weeks later Seven months after the accident the subluxation could be largely though not completely reduced The angle between the articular surface of the medial malleolus and the long axis of the tibia is 0° instead of 20° It would have been expedient to expose the medial malleolus to fix it with two crossed wires and to leave the cast on for 12 weeks

FIG 2677—Same case after 2 years Lateral subluxation of the talus as immobilization of 10 weeks was too short Severe valgus of talus The lateral half of the distal articular surface of the tibia is destroyed Tibiofibular gaping 1 cm long osteophyte along the anterior tibio fibular ligament Ankle joint thickened Pain on walking Later osteotomy was followed by considerable improvement

5. Have I performed the reduction immediately if the skin was severely stretched over a projecting fragment or if the foot was pale and cold from pressure on arteries?
6. Have I prepared the skin for local anesthesia simply by painting it with iodine and refrained from scrubbing it with benzene and alcohol since this might cause blisters and eczema?
7. Have I refrained from shaving the skin?
8. Have I refrained from greasing the skin of the leg?
9. Have I studied the roentgenograms to confirm the type of fracture and the extent of displacement and to determine the manner of reduction and the duration of immobilization?

10 Have I pressed away the edema before reduction?

11 Did I have the patient sitting or lying, with the knee flexed (figs 2644 to 2648) in order to relax the Achilles tendon (Vol I/figs 5, 6)?

12 Have I refrained from attempting reduction with the patients knee extended or the foot dorsiflexed (Vol I/fig 3) since this tightens the Achilles tendon?

13 Has the injured foot rested on the surgeon's knees and the uninjured foot on a stool or step?

14 Has a suitable roll been placed under the patient's thigh if he has a long lower leg?

15 Have I reduced a foot displaced outward by holding the lower leg with one hand two finger-breadths above the ankle medially and pressing the lateral malleolus inward with the other?

16 Have I refrained from supinating the forefoot? Supination cannot correct lateral subluxation at the ankle joint Supination of the forefoot causes flat-foot (fig 2519 c)

17 Have I used a plaster cast for immobilization, never traction?

18 Have I applied the cast at plantarflexion of 5° to 10° so that the sole of the foot forms an angle of 95° to 100° with the long axis of the lower leg

19 Have I avoided dorsiflexion since the talus wide in front, would drive the malleoli apart? The malleolar socket would remain wide and the joint would become loose

20 Have I *slightly supinated the heel and have I pronated the forefoot* to such an extent that the first and fifth metatarsal heads come to lie horizontal?

21 Have I placed a hemp cord on the dorsum of the foot and lower leg?

22 Have I glued a notched flannel strip with 3 to 4 longitudinal Mastisol strokes below the knee?

23 Have I applied the very wet dorsal plaster splint with its upper end at the middle of the flannel strip to avoid cutting the skin?

24 Has the plaster splint been placed on the posterior side of the lower leg and on the sole of the foot and then turned over the toes onto the back of the foot?

25 Have I notched the plaster splint at both sides of the heel?

26 Have I smoothed the lateral edges of the plaster splint so that they do not form the slightest ridge?

27 Have I fixed the plaster splint with a circular plaster bandage?

28 Have I applied the circular plaster roll in such a way that each turn progressed two finger breadths in order that the cast has uniform strength?

29 Have I turned down the flannel strip in order that there is no sharp edge at the upper end of the cast?

30 Have I, after the first plaster roll has been applied, folded the plaster slab back from the dorsum of the foot to the sole so that it extends to the tips of the toes and at the first and the fifth toe to the edge of the toenail?

31 Have I, after the second plaster roll has been applied, corrected re displacement if it occurred?

32 *Have I held the foot after reduction until the plaster hardened?*

33 Have I molded the toe plate in such a manner that it extends in the direction of the sole and does not curve upward (as in figs 2653 and 2655) in order that the toes may be freely exercised?

34 Have I protected the toes from the weight of the blankets with proper length of the toe plate as pain and flexion contractures may result if this is too short?

35 Have I asked the patient to lie down after the completion of the cast and placed the leg horizontally with the 5 cm foam rubber or cellulose roll under the Achilles tendon in order that no pressure is exerted on the heel?

36 Have I placed the 8 cm foam rubber or cellulose roll under the knee joint?

37 Have I taken anteroposterior and lateral roentgenograms with an inward rotation of 15° to 20°?

38 Have I removed the cast if roentgenograms showed that complete reduction was not achieved, and have I then corrected the displacement and applied a new cast?

39 Have I again taken anteroposterior and lateral roentgenograms with inward rotation of 15° to 20° after application of the second cast?

40 Have I continued to remove the cast and reapply a new cast and taken X-rays after every cast until the position was perfect?

41 Have I applied the cast in such a manner that it reaches to the webs of the toes on the extensor aspect If it is longer the toes cannot be extended, and if it is shorter edema will occur between the webs of the toes and the cast

42 Have I in an improperly applied cast pressed away such edema with foam rubber and then lengthened the cast to the webs of the toes?

43 Have I bent the upper edge of the cast if this was necessary to allow the knee to flex to a right angle?

44 Have I included the head of the fibula in the cast in order to avoid pero neal paralysis from pressure of the edge of the cast?

45 Have I felt the upper and lower cast edge from within to discover a sharp edge?

46 Have the plaster particles been washed from the toes before the patient left the cast room in order that the state of the circulation could be determined?

47 Have I split the cast through the last thread along the previously placed cord to avoid circulatory disturbances and pain?

48 Have I removed the plaster particles with a cotton applicator, a forceps or a vacuum cleaner?

49 Have I sketched in full size the initial X-ray findings over the fracture site?

50 Have I inscribed the cast (date of injury, date of reduction, date of application of the cast date of intended removal of the cast and time of

intended immobilization in weeks as well as the appointment time of the roentgen check, and the name of the resident and the supervising surgeon). See figure 2416



2678 June 2 1933 2679



2680 October 13 1937 2681 October 13 1937 2682 May 21 1938

FIG 2678—Roentgenogram of the ankle joint of a 28 year old patient who turned her ankle There was severe swelling ecchymosis and pain at the lateral and anterior aspect of the ankle joint The skin was intact

FIG 2679—Comparison roentgenogram in forced supination under local anesthesia The joint can be opened laterally to a distance of 14 mm

FIG 2680—Avulsion of the tip of the lateral malleolus Sustained by a 24 year old painter who slipped on a step Severe swelling and ecchymosis

FIG 2681—Comparison roentgenogram under local anesthesia in forced supination The joint can be opened laterally to a distance of 16 mm The avulsed tip of the lateral malleolus is displaced medially Supination adduction fracture stage 1 according to Lauge Hansen Treated in a walking cast for 10 weeks

FIG 2682—Check roentgenogram 7½ months later Bony union of the avulsed tip of the malleolus Patient resumed work four weeks after removal of the cast The ankle joint is stable and freely movable



2683 April 4 1938 2684 June 26 1938 2685 July 22 1938



2686 a March 1934 2686 b May 18 1934 2686 c July 28 1938

FIG 2683 – Avulsion of the tip of the lateral malleolus and vertical shearing fracture of the medial malleolus Medial dislocation of the foot half the width of the talus varus of 25° Sustained by a 56 year old woman who loaded with a heavy carpet fell down a high stairway Supination adduction fracture stage 2 according to Lauge Hansen

FIG 2684 – Check roentgenogram ten weeks later after removal of the cast Bony union in good position Demineralization

FIG 2685 – Check roentgenogram after 14 weeks Fracture line still clearly visible Normal mineralization Full range of active motion at the ankle joint Asymptomatic Patient resumed work 14 days before

FIG 2686 a – Transverse fracture of the lateral malleolus at the level of the ankle joint and vertical shearing fracture of the medial malleolus Medial dislocation of the foot of two thirds of the width of the talus varus of 35° Sustained by a 43 year old woman who fell 3 M from a ladder

FIG 2686 b – Check roentgenogram after 10 weeks on removal of the cast Bony union in good position Severe demineralization The ankle joint was freely movable seven weeks later

FIG 2686 c – Check roentgenogram after four years Old fracture line still visible Normal mineralization Ankle joint freely movable Asymptomatic Normal concave outline of the lateral side of the lateral malleolus at the level of the ankle joint restored

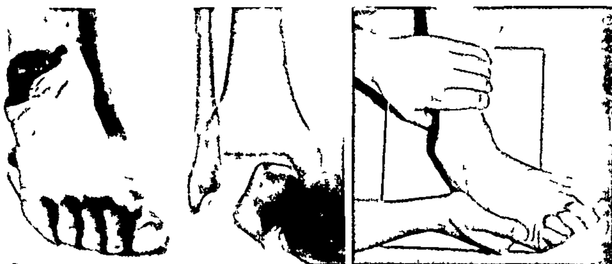
51 Have I placed the leg on a well wrapped Braun splint?
52 Have I drilled a hole through the toe plate between the second and third toe by which the foot could be suspended from the transverse bar of the splint?
53 Have I wrapped a paper bandage loosely over the cast so that the bed clothes are not stained by the ink?
54 Have I placed the supplementary U-support over the middle of the tibia (fig 2473)?
55 Have I placed the patient with the Braun splint in the prewarmed bed?
56 Have I placed the wooden box as a prop for the uninjured foot?
57 Has the patient fully extended his toes beginning the first day?
58 Have I in the presence of a beginning peroneal paralysis loosened the cast over the fibular head?
59 Have I placed a piece of foam rubber between the toe plate and the toes in case of a peroneal paralysis?
60 In the case of pain and increasing swelling have I further spread the split cast?
61 Have I on the third or fourth day pulled the split cast together with a bandage if it has become loose after the swelling has subsided in order that no new subluxation occurs?
62 Have I applied a short leg walking cast after 8 to 10 days when the swelling has subsided?
63 Have I pressed away any swelling that might be present?
64 Have I used three circular plaster rolls for the walking cast, rather than two as in the temporary cast?
65 Have I used four circular plaster rolls if the patient weighs more than 80 Kg?
66 Have I after application of the walking cast taken roentgenograms in both planes with an inward rotation of 15° to 20°
67 Have I immediately removed the short leg walking cast if the X-rays showed an imperfect position? Have I then corrected the position, applied a new cast and again taken X-rays in both planes?
68 Have I repeated this procedure until the position of the fragments was perfect?
69 Have I applied a walking heel as soon as the roentgenograms showed perfect position?
70 Have I trimmed the short leg walking cast and copied the inscription from the temporary cast?
71 Have I allowed the patient to then get up?
72 Has the patient walked one kilometer daily, spread out over the day in the first week and then increased this by one kilometer each week *if this did not produce pain?*
73 Have I made roentgenograms in both planes with inward rotation of 15° to 20° after one week and later every two weeks?
74 Have I removed the short leg walking cast if the X-rays revealed even the slightest displacement? Have I then corrected the displacement, re

applied the cast and repeated the X ray examination until the position was perfect?

75 Have I continued immobilization in plaster until the bones and ligaments have firmly united, namely 6 to 16 weeks? Premature removal will lead to redisplacement, limitation of motion and later painful arthrosis

76 Have I continued immobilization as outlined on page 1929?

77 Am I aware that immobilization that is extended 2 to 4 weeks longer than necessary causes no harm, but that too short immobilization produces permanent damage because the fragments will redisplace?



2686 d August 9 1948 2686 e 2686 f March 15 1939

Fig 2686 d —*Open* supination dislocation of the right foot Sustained by a 27 year old woman who fell from a truck The skin at the lateral side of the ankle was torn through for three fourths the circumference of the ankle The distal skin edge was wedged between the freely exposed lateral malleolus and the dislocated talus During wound excision it became apparent that all ligaments between the talus and the fibula were completely torn The peripheral skin edge was bloodless and therefore 1 cm was excised Insertion of a drain After reduction closure was effected by means of a proximally based flap Application of a long leg cast which was immediately split and windowed After 17 days a short leg walking cast was applied which was removed 16 weeks after the injury Three months later the scar was soft and mobile the joint slightly thickened and laterally stable Ankle joint 75° to 110° as compared to 75° to 120° on the left side Gait without limp and painless

Fig 2686 e — Held roentgenogram of the completely opened supination subluxation shown in fig 2686 d

Fig 2686 f —Position of the foot for the held roentgenogram in supination internal rotation The leg should not be externally rotated

78 Have I obtained new roentgenograms in the two planes with an inward rotation of 15° to 20° after removal of the plaster cast?

79 After the roentgenograms have I applied an Unna's paste boot from the webs of the toes to the knee?

80 Have I changed the Unna s paste boot if it has become too loose after a week and later every two to four weeks?

81 Have I continued treatment with the Unna's paste boot for 3 to 4 weeks in fractures with minimal displacement and 3 to 4 months in fractures with severe displacement or with varicose vein formation?

51 Have I placed the leg on a well wrapped Braun splint?
52 Have I drilled a hole through the toe plate between the second and third toe by which the foot could be suspended from the transverse bar of the splint?
53 Have I wrapped a paper bandage loosely over the cast so that the bed clothes are not stained by the ink?
54 Have I placed the supplementary U-support over the middle of the tibia (fig 2473)?
55 Have I placed the patient with the Braun splint in the prewarmed bed?
56 Have I placed the wooden box as a prop for the uninjured foot?
57 Has the patient fully extended his toes beginning the first day?
58 Have I in the presence of a beginning peroneal paralysis loosened the cast over the fibular head?
59 Have I placed a piece of foam rubber between the toe plate and the toes in case of a peroneal paralysis?
60 In the case of pain and increasing swelling have I further spread the split cast?
61 Have I on the third or fourth day pulled the split cast together with a bandage if it has become loose after the swelling has subsided in order that no new subluxation occurs?
62 Have I applied a short leg walking cast after 8 to 10 days when the swelling has subsided?
63 Have I pressed away any swelling that might be present?
64 Have I used three circular plaster rolls for the walking cast rather than two as in the temporary cast?
65 Have I used four circular plaster rolls if the patient weighs more than 80 Kg ?
66 Have I after application of the walking cast taken roentgenograms in both planes with an inward rotation of 15° to 20°
67 Have I immediately removed the short leg walking cast if the X-rays showed an imperfect position? Have I then corrected the position applied a new cast and again taken X rays in both planes?
68 Have I repeated this procedure until the position of the fragments was perfect?
69 Have I applied a walking heel as soon as the roentgenograms showed *perfect position*?
70 Have I trimmed the short leg walking cast and copied the inscription from the temporary cast?
71 Have I allowed the patient to then get up?
72 Has the patient walked one kilometer daily, spread out over the day, in the first week and then increased this by one kilometer each week *if this did not produce pain*?
73 Have I made roentgenograms in both planes with inward rotation of 15° to 20° after one week and later every two weeks?
74 Have I removed the short leg walking cast if the X-rays revealed even the slightest displacement? Have I then corrected the displacement, re

1 In the reduction did I place one hand two finger-breadths above the ankle joint at the *outer side* and the other at the level of the ankle joint at the inner side and then did I push the medially displaced foot *outwards* rather than displace it farther inwards?
2 Have I examined the roentgenograms to determine whether the normal concavity of the outer contour of the lateral malleolus at the level of the ankle joint has been restored as in figures 2567, 2685?

Treatment of Supination-External Rotation Fractures of the Malleoli

The same materials and preparation are required for *reduction* and *immobilization* as for pronation-abduction fractures (see p 1917)

As a rule reduction was carried out without difficulty if none of the obstacles described on page 1950 was present If there is shortening as in figs 2633, 2634 the mid foot should be grasped with one hand and the heel with the other, the foot is then pulled downward, forward and turned inward Thus one corrects the shortening, the posterior subluxation and the outward rotation If there is still an outward subluxation, this is corrected as in pronation abduction fractures by grasping the leg on the medial side above the ankle with one hand and pressing the outer malleolus with the other hand inward

Lauge-Hansen describes the reduction as follows In a fracture-dislocation of the right ankle joint the mid-foot is grasped at its plantar and medial aspect with the right hand and the heel from behind from the left The foot is then supinated and rotated outwards around the axis of the tibia Then the heel of the plantarflexed foot is pulled in a manner similar to removing a boot The foot is then pulled forwards with one hand while counterpressure is maintained on the ventral side of the lower leg with the other Then the foot is rotated inwards with simultaneous pronation and dorsiflexion to a right angle Thus the fragments lock together so that the fracture becomes stable The temporary cast is applied in this position in a manner described on page 1920 and the cast is split

Immobilization in Unstable Fracture Dislocations

Holding of the Foot during Application of the Cast If the outer and inner malleoli and a large wedge of the joint surface of the tibia are fractured and the capsule and ligaments are completely torn as in stage 4 so that the foot remains fastened only by its soft tissues, redislocation often occurs even after good reduction if the foot is not held continuously with both hands while the cast is applied by someone else

Application of a Long Cast in Unstable Fractures A lower leg cast which is split and bent open does not give enough stability to unstable fractures with a large posterior wedge The cast must therefore be lengthened up to midthigh One first applies a lower leg cast as described on page 1920 When the roentgenograms in both planes show exact reduction, the cast is lengthened to midthigh in the manner described on page 1830 and is immediately split through the last thread before the patient leaves the cast room

82 Has the patient exercised his ankles from a sitting position by repeated vigorous plantarflexion with the toes on the floor?
83 Has the patient begun to stand and to walk on tiptoe after 3 to 4 weeks?
84 Has the patient, if young, attempted deep knee bends *if no pain appeared?*
85 Have I avoided massage and passive exercises?
86 *Have painful exercises been avoided?*
87 At the conclusion of treatment have I obtained new roentgenograms in both planes in an inward rotation of 15° to 20°?

Treatment of Supination-Adduction Fractures of the Malleoli

The same preparation and materials are required for *reduction and immobilization* as for pronation-abduction fractures (p 1917)

Reduction Under general or local anesthesia the patient sits or lies on the table with the knee flexed and the leg hanging over the edge of the table as for reduction of pronation-abduction fractures (fig 2644) Then the leg is grasped with one hand above the ankle on the *lateral side* and with the other at the level of the ankle on the medial side and the foot is forcefully pressed laterally One can thus satisfactorily reduce both malleoli If the medial malleolus remains 1 to 2 mm higher than normal long observation has shown that this causes no harm (fig 2686 c) The impacted portion of the medial side of the joint surface of the tibia does not allow itself to be pulled out This also does not impair future function (figs 2685 2686 c, 2750, 2751) If the medial malleolus cannot be replaced because of interposed fragments these must be operatively removed

Immobilization Traction should never be used following reduction but rather a temporary short leg cast is applied as in the pronation abduction fractures (see p 1920) except that one must hold the *outer side* of the lower leg and press the foot *laterally* while the plaster is hardening We have seen many cases in which the foot has been pressed medially during reduction and application of the cast Displacement was then greater than before the attempted reduction (fig 2580)

Check roentgenograms are made in both planes with the foot in 15° to 20° inward rotation It is particularly important that the *normal concavity of the outer side of the fibula at the level of the joint space be reproduced* and demonstrated in the roentgenogram (figs 2635 b 2685 2686 c)

Trimming inscription immediate splitting of the cast through the last thread, *placement in bed on the Braun splint exercises application of the short leg walking cast and further treatment* are carried out in the same manner as in pronation-abduction fractures (see pp 1921—1932)

Duration of Immobilization Plaster immobilization must as a rule be continued 10 to 12 weeks

Questions We Should Ask Ourselves in Order to Avoid Failures in the Treatment of Supination-Adduction Fractures of the Malleoli

To the points listed on pages 1933—1940 for pronation-abduction fractures the following questions must be added

1. In the reduction did I place one hand two finger breadths above the ankle joint at the *outer side* and the other at the level of the ankle joint at the inner side and then did I push the medially displaced foot *outwards* rather than displace it farther inwards?
2. Have I examined the roentgenograms to determine whether the normal *concavity of the outer contour of the lateral malleolus at the level of the* ankle joint has been restored as in figure 2567 2685?

Treatment of Supination External Rotation Fractures of the Malleoli

The same materials and preparation are required for *reduction* and *immobilization* as for pronation abduction fractures (see p 1917)

As a rule reduction was carried out without difficulty if none of the obstacles described on page 1930 was present If there is shortening as in figs 2633 2634 the mid foot should be grasped with one hand and the heel with the other the foot is then pulled downward, forward and turned inward Thus one corrects the shortening the posterior subluxation and the outward rotation If there is still an outward subluxation this is corrected as in pronation abduction fractures by grasping the leg on the medial side above the ankle with one hand and pressing the outer malleolus with the other hand inward

Lauge Hansen describes the reduction as follows In a fracture dislocation of the right ankle joint the mid foot is grasped at its plantar and medial aspect with the right hand and the heel from behind from the left The foot is then supinated and rotated outwards around the axis of the tibia Then the heel of the plantarflexed foot is pulled in a manner similar to removing a boot The foot is then pulled forwards with one hand while counterpressure is maintained on the ventral side of the lower leg with the other Then the foot is rotated inwards with simultaneous pronation and dorsiflexion to a right angle Thus the fragments lock together so that the fracture becomes stable The temporary cast is applied in this position in a manner described on page 1920 and the cast is split

Immobilization in Unstable Fracture Dislocations

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Duration of Immobilization Plaster immobilization must as a rule be continued 10 to 12 weeks

Questions We Should Ask Ourselves in Order to Avoid Failures in the Treatment of Supination-Adduction Fractures of the Malleoli

To the points listed on pages 1933—1940 for pronation-abduction fractures the following questions must be added

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2 Have I examined the roentgenograms to determine whether the normal concavity of the outer contour of the lateral malleolus at the level of the ankle joint has been restored as in figures 2567, 2655?

Treatment of Supination External Rotation Fractures of the Malleoli

The same materials and preparation are required for *reduction* and *immobilization* as for pronation abduction fractures (see p 1917)

As a rule reduction was carried out without difficulty if none of the obstacles described on page 1950 was present If there is shortening as in figs 2633, 2634 the mid foot should be grasped with one hand and the heel with the other, the foot is then pulled downward, forward and turned inward Thus one corrects the shortening the posterior subluxation and the outward rotation If there is still an outward subluxation, this is corrected as in pronation abduction fractures by grasping the leg on the medial side above the ankle with one hand and pressing the outer malleolus with the other hand inward

Lauge Hansen describes the reduction as follows In a fracture dislocation of the right ankle joint the mid foot is grasped at its plantar and medial aspect with the right hand and the heel from behind from the left The foot is then supinated and rotated outwards around the axis of the tibia Then the heel of the plantarflexed foot is pulled in a manner similar to removing a boot The foot is then pulled forwards with one hand while counterpressure is maintained on the ventral side of the lower leg with the other Then the foot is rotated inwards with simultaneous pronation and dorsiflexion to a right angle Thus the fragments lock together so that the fracture becomes stable The temporary cast is applied in this position in a manner described on page 1920 and the cast is split

Immobilization in Unstable Fracture Dislocations

Holding of the Foot during Application of the Cast If the outer and inner malleoli and a large wedge of the joint surface of the tibia are fractured and the capsule and ligaments are completely torn as in stage 4 so that the foot remains fastened only by its soft tissues, redislocation often occurs even after good reduction if the foot is not held continuously with both hands while the cast is applied by someone else

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2687, December 1 1926 2688



2689 February 26 1927 2690

FIG 2687 2688 — Supination external rotation fracture stage 4 Torsion fracture of the lateral malleolus at the level of the joint avulsion fracture of the anterior part of the medial malleolus posterolateral dislocation of the talus Compare wih fig 2611 c Only a small fragment is broken from the posterior edge of the tibia Compare with fig 2612 a The whole distal joint surface of the tibia is intact Sustained by a 36 year old man who slipped In spite of the gross displacement this fracture can be easily reduced The reduced position can be easily maintained permanently by an unpadded cast which is split immediately One week later a walking cast is applied for an additional 15 weeks

FIGS 2689 2690 — Same case twelve weeks after the accident immediately after removal of the cast Marked de mineralization The three fragments have healed in good position Normal position of talus This fracture dislocation was reduced and put in plaster one hour after the accident The cast was split immediately One week later a walking cast was applied for another 11 weeks with which the patient could walk without the help of a cane three days later Re examination showed a 5 mm lateral subluxation because the cast was removed after 12 weeks instead of 16 weeks




2691 February 26 1930 2692




2693 October 28 1930 2694

Figs 2691 2692 Severe fracture dislocation with displacement of the foot backward and upward Sustained by axial impaction in plantar flexion The anteroposterior view at first glance shows only minor changes namely an avulsion fracture of the tip of the medial malleolus and longitudinal fissures through the lateral malleolus No lateral displacement A big posterior wedge can be seen which is higher medially The lower tibial joint surface shows a double contour The severe displacement can be well seen only in the lateral view A big posterior wedge is sheared off the tibia Its base consists of more than one third of the lower tibial articular surface Compare with figs 2521 and 2523 A big posterior angulation wedge is broken out of the fibula Sustained by a 61 year old man who slipped on a wet floor and sat on his foot This type of fracture is difficult to treat since reduction can only be maintained by continuous traction or internal fixation by means of screws or crossed wires

Figs 2693 2694—Same case after reduction in the screw traction apparatus under local anesthesia A cast was applied the leg placed on a lower leg splint with 5 Kg traction for 6 weeks The cast was split immediately to avoid pressure disturbances At present we do not use a plaster cast when we treat these fracture dislocations with continuous traction (see p 1831) After six weeks the calcaneus pin was removed and a walking cast was applied for an additional 6 weeks The fracture united in good position with a minimal step at the lower tibial articular surface The ankle joint was freely movable four months later



2695 February 17 1932 2696



2697 March 9 1932 2698

Fig 2695 – Pronation external rotation fracture stage 4 with torsion fracture of the fibula a hand s breath above the ankle joint and avulsion fracture of the medial malleolus at joint level Avulsion of a small posterolateral wedge sustained by a woman weighing 90 Kg who slipped Compare with fig 2611 a

Fig 2696 —*Same case lateral view Posterior dislocation of the foot together with the fibula* Avulsion of a small posterior wedge The lower tibial articular surface is completely intact Compare with fig 2612 a This fracture dislocation can be easily treated if it is reduced well and immobilized for a long enough period

Fig 2697 2698 —Same case This fracture dislocation was reduced under local anesthesia two hours after the accident Position of the fragments and of the joint satisfactory in both planes Because of severe swelling the cast was immediately split Nine days later a new cast was applied Immobilization was continued for an additional 15 weeks in view of the complete tear of the tibio fibular ligaments in a woman weighing 90 Kg Mobility of the ankle was *almost free five months after injury*





2699 June [illegible] 1931 2700





2701 June 16 1931 2702

Fig 2699 — Severe impaction fracture of the left ankle joint with shearing off of a big posterior wedge This can be recognized from the double contour of the lower tibial articular surface Fracture of the medial malleolus The fracture of the lateral malleolus cannot be seen in the anteroposterior roentgenogram Sustained by a 59 year old woman who slipped on the stairs

Fig 2700 — Same case lateral view Dislocation of the foot backward and upward The medial malleolus is avulsed at joint level the lateral malleolus is broken obliquely at the same level Shearing off of a big posterior wedge whose base includes one third of the lower tibial articular surface Compare with figs 2521 and 2613 a This type of fracture can be kept in good position only by continuous traction or by internal fixation by means of screws (fig 2537 a) or crossed wires

Figs 2701 2702 — Same case after reduction with a heel clamp in the screw traction apparatus Good position in the anteroposterior picture The lateral picture shows good alignment of the big posterior wedge The talus is drawn too far anteriorly so that the joint space is widened posteriorly The clamp can be well seen in the calcaneus

Positioning of the Leg on an Oblique Splint Because the knee is straight, the leg is not placed on a Braun splint as described on page 1926 but is placed on an oblique splint (fig 2485 a)

Positioning in bed and *further care* until the application of a short leg walking cast are carried out in the manner described on pages 1927, 1928





2703 April 2 1937 2704

Figs 2703 2704 —Pronation external rotation fracture stage 4 with complete dislocation of the foot outward and backward Transverse avulsion of the entire medial malleolus and fracture of the fibula 6 cm above the joint Sustained by a 40 year old truck driver who slipped under the wheel of his car In the anteroposterior picture the foot is seen from the side Behind the lateral malleolus there is a 5 by 20 mm piece of bone which corresponds to the posterior ligamentous insertion In the lateral picture of the tibia the foot — rotated externally through 90° — is seen from in front The medial malleolus lies transversely below the tibial joint surface Complete disruption of the tibiofibular joint The 5 by 20 mm flake of bone is visible as a joint shadow anterior to the fibula and proximal to the talus Torsion fracture of the fibula 8 cm above the ankle joint Reduction under local anesthesia was easy The plaster cast was split immediately Twelve days later a walking cast was applied for an additional four months

Application of the Lower Leg Walking Cast When the swelling has subsided after 8 to 14 days a short leg walking cast is applied It usually affords adequate protection even in the severest supination-external rotation fractures Lengthening to midthigh is not necessary unless redisplacement subsequently occurs

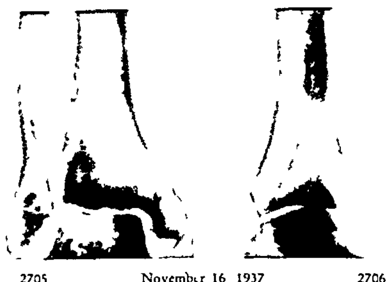
Further care in the walking cast and after its removal is carried out in the same manner as in pronation abduction fractures (see pp 1928—1932)

Duration of Immobilization Immobilization especially with supination external rotation fractures of stage 4 with widening of the ankle mortise as a result of tearing of the deltoid ligament and complete dislocation (fig 2720) must be continued long enough as a rule 16 weeks

Questions We Should Ask Ourselves in Order to Avoid Failures in the Treatment of Supination-External Rotation Fractures

Besides those given on pages 1933—1940 for pronation abduction fractures one should ask the following questions

1 In unstable fractures have I held the ankle joint with both hands after reduction and has someone else then applied the cast?



2705 November 16 1937 2706

Figs 2705 2706 —Same case seven months later Bony union in good position Normal mineralization Ankle joint stable movable through half its normal range

2 In unstable fractures have I lengthened the temporary cast to mid-thigh?

3 Have I in stage 4 immobilized the ankle for 16 weeks?

Treatment of Pronation-External Rotation Fractures of the Malleoli

The same materials and preparation are required for *reduction* and *immobilization* as for pronation-abduction fractures (see p 1917)

Reduction The patient sits or lies in the same manner as with pronation-abduction fracture (see page 1919) The foot is pronated and then rotated outwards, pulled forwards and then rotated inwards Then the foot is pushed inwards by pressure on the lateral malleolus with corresponding counterpressure on the inner side of the leg The widening of the ankle mortise is thus corrected If a mild varus position is produced at the fracture site of the fibula (fig 2705) it can be corrected by pressure on this point

Immobilization The temporary bed cast is applied in the manner described on page 1920 In unstable fractures the ankle is held with both hands after reduction while the cast is applied by someone else (see p 1941) In the

presence of marked displacement a temporary long leg bed cast is applied (p 1941)

Roentgen control and further treatment is carried out as for pronation abduction fractures (pp 1921—1932)

Duration of Immobilization Immobilization especially in the presence of wide separation of the ankle mortise must be continued long enough and in cases as shown in figures 2622, 2637—2640 not less than 16 weeks

Questions We Should Ask Ourselves in Order to Avoid Failures in the Treatment of Pronation-External Rotation Fractures

Besides those questions asked for pronation-abduction fractures on pages 1933—1940 the following should be added

1 In unstable fractures have I after reduction held the ankle joint with both hands until someone else has applied the cast?
2 With unstable fractures especially those with a large dorsal wedge have I lengthened the temporary bed cast to the mid-thigh?
3 In the presence of marked widening of the ankle mortise have I continued immobilization for 16 weeks?

Comparison of the Supination and Pronation Types of External-Rotation Fractures of the Malleoli with Those Anterior and Posterior Shearing Fractures Incurred by Impact in the Long Axis during Plantar- or Dorsiflexion

It is important to differentiate those fractures which follow external rotation from those shearing fractures that follow a longitudinal impact, because not only the mechanism of production but also the treatment and prognosis are entirely different The differences are clearly shown in figures 2687—2706

The *mechanism of the supination external rotation* fractures is shown experimentally on page 1897 and clinically on page 1899 and that of the posterior and anterior shearing fractures on pages 1820 1821 and figures 2521 —2526, 2535—2538

Diagnosis The characteristic sign of the *supination-external rotation fracture* is the spiral fracture of the lateral malleolus, which begins anteriorly and distally at the level of the ankle joint and ascends proximally and posteriorly (figs 2615 A 2616, 2634, 2687, 2718 2720) There is also usually avulsion of a variable-sized marginal fragment from the posterior edge of the tibia The lower joint surface of the tibia is usually largely or entirely intact (fig 2704) The medial malleolus may be broken off (figs 2687, 2704) or intact (figs 2718, 2720) The foot is dislocated outward and backward Particular attention should be paid to those fractures in which the outer malleolus is fractured while the inner one remains intact In these cases one should attempt to produce a knock by striking the medial malleolus with the talus and stress roentgenograms should be made (Vol I/figs 85—88, figs 2666 to 2669) One will often find a widening of the ankle mortise, as the deltoid ligament is torn If one omits the stress roentgenograms and therefore fails to immobilize long enough, subluxation and permanent damage will result

The mechanism of the posterior shearing fracture which results from axial impaction in strong plantarflexion is described on page 1820 and in figure 2521

Diagnosis Characteristic is the large dorsal tibia wedge and the posterior dislocation The base of the dorsal wedge is much wider on the medial side than on the lateral so much so that the tendon groove of the medial malleolus may be included or the entire medial malleolus In supination external rotation fractures, on the order hand the base of the posterior wedge is wider on the lateral side The lateral malleolus is fractured at joint level as in plantarflexion fractures The fracture also extends from anterodistally to posteroproximally The fracture surfaces are not spiral but plane because the malleolus has been split and not twisted off The tip is frequently broken off (fig 2692) Since the foot is dislocated only posteriorly and not laterally, the fracture of the lateral malleolus may not be visible (fig 2699) or may be seen only with difficulty (fig 2691) in the anteroposterior roentgenogram The double contour of the two approximately equal sized fragments can be seen in the anteroposterior roentgenogram The lateral roentgenogram shows the large dorsal shearing wedge which includes approximately half of the lower surface of the tibia Therefore this fracture is usually unstable after reduction while external rotation fractures are usually stable to a considerable degree

Treatment Because these shearing fractures are unstable, they must be treated by osteosynthesis or by traction while the supination external rotation fractures should never be treated by traction but in plaster

The mechanism of anterior shearing fractures by axial impaction in pronounced dorsiflexion is described on page 1821 and figure 1522

Diagnosis Characteristic is the shearing off of a large anterior wedge which is often overlooked when the displacement is slight as in figures 2525 and 2535 The medial malleolus is frequently split off while the outer remains intact (figs 2524—2526 2535, 2536)

Treatment This fracture can be easily reduced but good position can be maintained only by means of screws or with crossed wires (figs 2535, 2536)

The *mechanism* of the *pronation-external rotation fractures* is showen experimentally and clinically on pages 1900, 1901

Diagnosis The characteristic finding in pronation external rotation fractures is the spiral fracture of the fibula 6 to 8 cm above the ankle joint (figs 2611, 2611 a, 2615 D, 2695, 2703) or higher (figs 2621, 2637) In addition a small wedge is usually torn away from the posterior tibial margin The medial malleolus is usually torn off (figs 2695 2703) If the fibula is fractured at a high level the medial malleolus may remain intact (figs 2622—2624) The prognosis depends on the extent of the widening of the mortise This can be demonstrated only by stress roentgenograms (figs 2637—2640) In fractures of both the medial malleolus and the fibula widening of the mortise occurs between the tibia and fibula (figs 2611 a, 2638 2695, 2704) If the medial malleolus is not fractured but instead the deltoid ligament is torn through widening of the mortise between the tibia and fibula occurs and in addition between the medial malleolus and the talus (figs 2610 a 2610 b, 2611, 2622 to 2624) The presence of ligamentous tears demands longer immobilization

than the corresponding fractures of the medial malleolus Particularly in this type of injury with intact medial malleolus and therefore torn deltoid ligament, permanent disability is most frequently found because their severity is not recognized (figs 2622, 2755)

The inexperienced usually considers those shearing fractures produced by axial impaction in plantarflexion, which usually show only a dorsal dislocation (figs 2691, 2692) and those shearing fractures produced by axial impaction in dorsiflexion, which only have a ventral subluxation which is usually hard to recognize)figs 2525, 2535) as less severe than the supination and pronation external rotation fractures with their striking posterolateral dislocation In reality the axial impaction fractures are much more serious than the external rotation fractures

Obstacles in Reduction in Fractures of the Malleoli

With adequate anesthesia closed reduction is successful in most cases unless the following obstacles which require surgical intervention are present

1 Interposition of a fascia-periosteal band which remains attached anteriorly and posteriorly and is pulled into the fracture cleft and prevents the apposition of the fragments (figs 2707, 2708, 2711)

2 Interposition of bits of torn fascia and periosteum that have been driven between the fragments These obstacles described under 1 and 2 are the commonest

3 Interposition of a long periostal flap, first to my knowledge described by Beck [1] I have seen this form only seldom (figs 2710, 2716)

4 Interposition of small sheared off fragments of bone and cartilage at the dorsal side of the tibia (fig 2617 b) or at the lateral malleolus They are sometimes also seen on the medial side in supination adduction fractures

5 Interposition of the tendon of the tibialis posticus muscle between the medial malleolus and the tibia (2719)

6 Interposition of the tendon of the tibialis posticus muscle between the lateral malleolus and the fibula (fig 2720)

I have seen interposition of the tendon of the tibialis posticus muscle only in these two cases and have never seen it described elsewhere

7 Blocking of reduction by jagged margins of the fracture surfaces of the lateral malleolus which prevent accurate apposition of the fragments (figs 2732, 2776)

8 Medial displacement of the proximal fragment of the fibula by full shaft width behind the tibia and locking in this position in supination-external rotation fractures stage 4 with intact medial malleolus (fig 2718) or posterolateral displacement oft the lateral malleolus by its full shaft width (fig 2728) I have seen this type in my series only twice and have seen two additional cases as consultant Watson Jones has published a similar case in his book in which the lateral malleolus was displaced posteriorly and medially and the peroneus tendons were interposed between the fragments

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1 Beck A Zur Frage der operativen Behandlung der Luxationsfraktur des Fußgelenkes Dtsch Zschr Chir *228* 289 1930

9 Twisting of the medial malleolus around its long axis (fig 2715)
10 Tilting of the medial malleolus (fig 2716)
11 Tilting of the lateral malleolus (fig 2717)

Operative Treatment of Fresh Fractures of the Malleoli

Indication for Operation The four groups of the usual fresh malleolar fractures are treated surgically much too often Open reduction is necessary only if it is not possible to oppose the fragments because of one of the eleven obstacles listed above Fresh disruption of the mortise should not be treated surgically

Impaction fractures with a ventral wedge resulting from dorsiflexion should always be treated surgically (fig 2535 a, 2536 a) while in those resulting from plantarflexion with a large dorsal wedge surgery is often desirable (fig 2537 a)

Time of Operation It is best to carry out the operation in the first few hours before the development of severe swelling If this is not possible one should wait until the swelling has subsided and the skin is again normal This usually takes 8 to 14 days

Operation The operation is carried out under local or preferably under general anesthesia in a bloodless field maintained by tourniquet We formerly exposed the medial malleolus with a longitudinal incision, removed the obstacle to reduction, apposed the malleolus without fixation and closed the skin without burying sutures or ligatures (figs 2715 a, 2752 a), because in many cases treated elsewhere we have seen that the foreign bodies used for fixation led to infection of the joint In the respective records these were referred to as harmless fistulas Most of these patients however had already been hospitalized for months In Vol I/p 48 (case 2) such a record is summarized

Osteosynthesis with Screws and Wires Since antibiotics have become available we have fixed the medial malleolus with a screw (fig 2626) or a wire loop after reduction To do this the periosteum had to be partly elevated from the medial malleolus In some cases it was difficult to fix the malleolus with a screw or a wire loop especially when it was comminuted

Osteosynthesis with Crossed Wires In 1954 following the suggestion of Jorg Bohler we began to expose the fracture through a transverse incision removing the interposed tissue and with the malleolus held by a single hook and to fix it with two crossed percutaneous wires (figs 2716 a, 2733, 2734, 2828) The second wire can be placed from proximal anteriorly rather than distal posteriorly Through this incision the whole fracture can be surveyed and the malleolus can be exactly apposed The periosteum need not be elevated

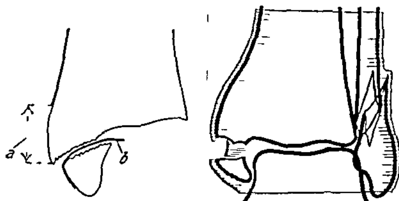
X-ray Control After the placement of the wires roentgenograms should be made in both planes with inward rotation of 20° If they show satisfactory position the skin is closed The wires are cut below the skin The operation formerly required considerable time but is performed rapidly now

Osteosynthesis of the Large Posterior Shearing Wedge with Crossed Wires In the next case in which a large posterior shearing wedge is found which

usually includes the larger part of the medial malleolus we shall attempt open reduction through a transverse incision with Steinmann pin traction through the os calcis and fixation by means of percutaneously introduced crossed wires without introducing wires or screws from posteriorly



2707 March 19 1938 2708 March 21 1938 2709 March 28 1938



2710 2711

FIG 2707—Supination external rotation fracture Torsion fracture of the lateral malleolus at joint level and avulsion of the anterior part of the medial malleolus The fracture space is 6 mm wide at the medial malleolus Lateral subluxation of the talus of 2 mm Compare with fig 2611 c Sustained by a 40 year old laborer when a wooden railroad tie fell on his foot

FIG 2708—Same case in plaster after attempted reduction The position is not improved In spite of repeated attempts it was not possible to replace the medial malleolus

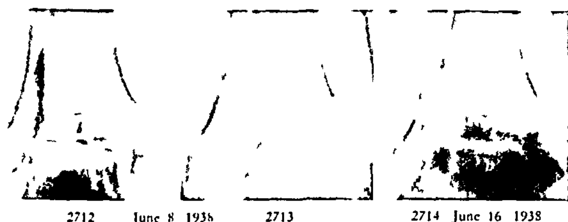
FIG 2709—Same case after operative exposure of the medial malleolus At operation a 3 mm wide strip of periosteum and fascia was found interposed in the fracture After it was divided and removed the medial malleolus could easily be replaced The lateral displacement of the lateral malleolus has also disappeared Internal fixation was not required

FIG 2710—Sketch by Beck A wide periosteal flap which ha separated from proximally is interposed between the fragments

FIG 2711 -Sketch for figs 2707 2708 A transverse strip of periosteum and fascia which remains attached posteriorly and anteriorly is interposed between the fragments

Operation in the Presence of Interposition of Small Fragments of Bone and Cartilage If a small bone fragment is present in the dorsal portion of the fracture as in fig 2717 b the fracture site of the lateral malleolus is exposed through a lateral longitudinal incision and the bone fragment is removed The posterior wedge and the lateral malleolus can then be properly replaced The fragments of the lateral malleolus can be held together with a wire loop (fig 2717 c)

Operation in the Presence of Interposition of Tendons If the medial malleolus is involved it is exposed through a transverse incision or if the lateral is involved it is exposed through a slightly curved longitudinal incision The tendon is then freed The medial malleolus can be fixed with two crossed wires as in figure 2716 a and the lateral with a wire loop (figs 2716 c, 2718 b)



2712 June 8 1938 2713 2714 June 16 1938

Fig 2712 —This fracture has been designated by Lauge Hansen as pronation abduction fracture stage I Avulsion of the medial malleolus which is displaced medially and tipped into a valgus position so that the fracture surfaces gape 5 mm on the medial side Sustained by a 29 year old carpenter in a fall from a scaffold

Fig 2713 Same case in plaster following three attempts at reduction

Fig 2714 Same case following operative exposure of the medial malleolus As in the case shown in fig 2709 a transverse periosteum fascia strip (fig 2711) was interposed between the fragments After its removal the medial malleolus could be satisfactorily apposed Internal fixation was not carried out

Immobilization after Internal Fixation After operation the temporary bed cast is applied in the manner described on page 1920 After the X-ray control this is *immediately split through the last thread* If healing is uncomplicated a short leg cast is applied after two weeks Further management is carried out as for the unoperated cases (see pp 1925—1931)

Duration of Immobilization The cast remains 10 to 16 weeks according to the severity of the original displacement In complete disruption of the ankle mortise as in figure 2733 immobilization must be continued four months

Removal of the Crossed Wires The wires should be withdrawn after removal of the cast if the skin is normal As they lie near the surface they usually can be removed through a small stab wound

Further care in an Unna s paste boot and exercises are described on pages 1930 1931

Incorrect Indication for Surgical Treatment of Fresh Malleolar Fractures

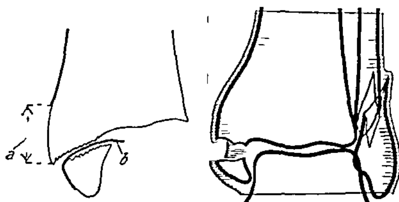
We have found four types of incorrect indication

1 Operation in fresh disruption of the mortise
2 Operation in presumed disruption of the mortise

usually includes the larger part of the medial malleolus we shall attempt open reduction through a transverse incision with Steinmann pin traction through the os calcis and fixation by means of percutaneously introduced crossed wires without introducing wires or screws from posteriorly



2707 March 19 1938 2708 March 21 1938 2709 March 28 1938



2710 2711

Fig 2707 —Supination external rotation fracture Torsion fracture of the lateral malleolus at joint level and avulsion of the anterior part of the medial malleolus The fracture space is 6 mm wide at the medial malleolus Lateral subluxation of the talus of 2 mm Compare with fig 2611 c Sustained by a 40 year old laborer when a wooden railroad tie fell on his foot

Fig 2708 —Same case in plaster after attempted reduction The position is not improved In spite of repeated attempts it was not possible to replace the medial malleolus

Fig 2709 —Same case after operative exposure of the medial malleolus At operation a 3 mm wide strip of periosteum and fascia was found interposed in the fracture After it was divided and removed the medial malleolus could easily be replaced The lateral displacement of the lateral malleolus has also disappeared Internal fixation was not required

Fig 2710 —Sketch by Beck A wide periosteal flap which has separated from proximally is interposed between the fragments

Fig 2711 -Sketch for figs 2707 2708 A transverse strip of periosteum and fascia which remains attached posteriorly and anteriorly is interposed between the fragments

Operation in the Presence of Interposition of Small Fragments of Bone and Cartilage If a small bone fragment is present in the dorsal portion of the fracture as in fig 2717 b the fracture site of the lateral malleolus is exposed through a lateral longitudinal incision and the bone fragment is removed The posterior wedge and the lateral malleolus can then be properly replaced The fragments of the lateral malleolus can be held together with a wire loop (fig 2717 c)

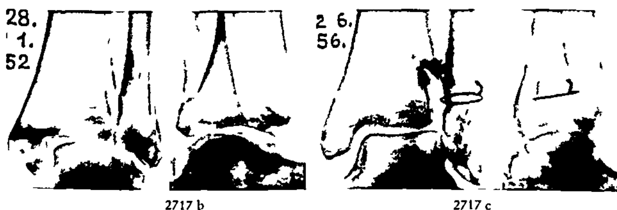
1 *Operation for Disruption of the Mortise* Surgery is currently most commonly carried out for presumed or actual disruption of the mortise The distal fragment of the fibula is usually fixed to the tibia with two screws (figs 2715 b 2726 a, 2727 a) Some use bolts threaded on both ends and nuts (fig 2723 a) or apply plates on both malleoli and bolt them together



2717 2717 a

Fig 2717 This fracture is classified by Lauge Hansen as pronation abduction fracture He wrote to me as follows (1) Fractura malleoli medialis (2) Tear of the lig malleoli lateralis anterius and posterius (3) Slightly oblique transverse fracture of the supramalleolar portion of the fibula Small intermediate fragment laterally He included a drawing in which the lateral bending wedge of the fibula is shown *Treatment* The fracture was reduced operatively by Dr Hofer The fragments were approximated by means of three wire loops It would have been simpler to use two crossed wires

Fig 2717 a – Same case following operation



2717 b 2717 c

Fig 2717 b – Supination external rotation fracture stage IV Sustained by a 29 year old woman who slipped and fell on a step Torsion fracture of the lateral malleolus at the level of the joint Avulsion of a thin dorsal wedge and shearing off of a small intermediate wedge which is located between the tibia and the posterior wedge Wide gap between the fragments of the lateral malleolus Avulsion of the medial malleolus *Treatment* Since it was not possible in spite of several attempts to achieve reduction the lateral malleolus was exposed The fracture site of the tibia was easily accessible through the fracture of the fibula and the intermediate fragment was readily removed Thereupon both malleoli and the posterior bone flake were readily replaced by minimal pressure on the heel The fragments of the fibula were fixed with a wire loop

Fig 2717 c – Same case after 4½ years Bony union in good position At the tip of the peripheral fragment of the fibula periosteal ossification has developed which is behind the tibiofibular joint All joints are freely mobile No complaints Walks without a limp

3 Re-attachment of posterior marginal fragments of the tibia by means of screws
4 Medullary nailing of fractures of the lateral malleolus



2715 2715 a

Fig 2715 —This fracture was classified by Lauge Hansen as pronation abduction fracture stage 1 The medial malleolus is rotated 180° round its longitudinal axis Treatment exposure of the fracture site with a curved longitudinal incision turning the malleolus which was attached to the deltoid ligament Accurate replacement Suture of the skin without internal fixation Temporary cast for two weeks and walking cast for an additional four weeks.
Fig 2715 a —Same case after 10 weeks The fracture line has disappeared Complete function



2716 April 21 1956 2716 a May 25 1956

Fig 2716 —Pronation external rotation fracture stage 4 Incurred by a 29 year old laborer who slipped and fell while carrying heavy iron rods Fracture of the fibula 6 cm above the ankle joint Avulsion of the medial malleolus which then assumed a transverse position so that its fracture surface is parallel to the skin Its protrusion was visible and palpable The skin was stretched over it and was bloodless Lateral subluxation and disruption of the joint between tibia and fibula *Treatment* exposure of the fracture site with a 6 cm transverse incision under tourniquet and anesthesia A 2 cm by 5 cm strip of periosteum is interposed between the fracture surface and extends into the joint It is removed Then the medial malleolus is accurately replaced on the tibia and held in place with a hook 2 wires are then drilled into the fragment percutaneously in such a manner that they cross These are cut off below the level of the skin after suture of the skin Then a temporary cast is applied that is split immediately and is followed in 16 days by a short leg walking cast for an additional ten weeks

Fig 2716 a —Good position of the medial malleolus and of the two wires Slight gap between tibia and fibula

1 *Operation for Disruption of the Mortise* Surgery is currently most commonly carried out for presumed or actual disruption of the mortise. The distal fragment of the fibula is usually fixed to the tibia with two screws (figs 2715 b 2726 a 2727 a) Some use bolts threaded on both ends and nuts (fig 2723 a) or apply plates on both malleoli and bolt them together



Fig 2717 This fracture is classified by Lauge Hansen as pronation abduction fracture He wrote to me as follows (1) Fractura malleoli medialis (2) Tear of the lig malleoli lateralis anterius and posterius (3) Slightly oblique transverse fracture of the supramalleolar portion of the fibula Small intermediate fragment laterally He included a drawing in which the lateral bending wedge of the fibula is shown *Treatment* The fracture was reduced operatively by Dr Hofer The fragments were approximated by means of three wire loops. It would have been simpler to use two crossed wires

Fig 2717 a Same case following operation

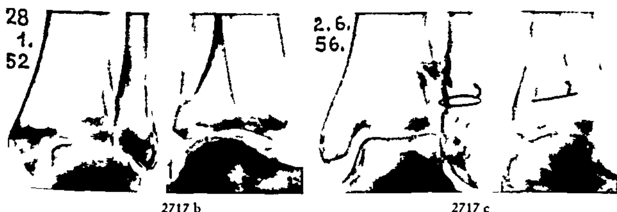


Fig 2717 b Supination external rotation fracture stage IV Sustained by a 29 year old woman who slipped and fell on a step Torsion fracture of the lateral malleolus at the level of the joint Avulsion of a thin dorsal wedge and shearing off of a small intermediate wedge which is located between the tibia and the posterior wedge Wide gap between the fragments of the lateral malleolus Avulsion of the medial malleolus *Treatment* Since it was not possible in spite of several attempts to achieve reduction the lateral malleolus was exposed The fracture site of the tibia was easily accessible through the fracture of the fibula and the intermediate fragment was readily removed Thereupon both malleoli and the posterior bone flake were readily replaced by minimal pressure on the heel The fragments of the fibula were fixed with a wire loop

Fig 2717 c—Same case after 4$^1/_2$ years Bony union in good position At the tip of the peripheral fragment of the fibula periosteal ossification has developed which is behind the tibiofibular joint All joints are freely mobile No complaints Walks without a limp

(fig 2724 a) It should be stressed that it is usually not difficult to correct the separation conservatively in all four types of mortise disruption With good reduction and sufficiently long immobilization solid healing always occurs even when the talus is dislocated by half or all of its width (figs 2637—2640,



2718 December 26 1954

Fig 2718 —Supination external rotation fracture stage 4 according to Lauge Hansen without fracture of the medial malleolus Sustained by a 55 year old merchant in a fall while skiing The shaft of the fibula is displaced a full shaft width dorsomedially from the lateral malleolus



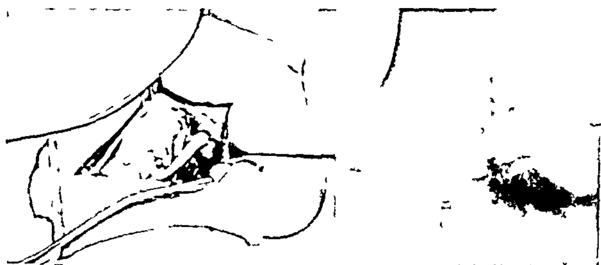
2718 a December 28 1954 2718 b June 20, 1955

Fig 2718 a – The fibula was exposed by a curved lateral incision The fracture surfaces of the lateral malleolus lay directly under the skin The shaft of the fibula lay in the musculature behind the tibia It could be freed and replaced only with difficulty Fixed with a wire loop Temporary cast for two weeks followed by a short leg walking cast for twelve weeks Compare with fig 2721

Fig 2718 b —Same case after six months Good position of the fragments No bone atrophy Ankle not swollen Mobility from 85° to 100° as compared to 80° to 115° on the right Pain on prolonged walking

2666—2669, 2695—2706, 2725 c, 2733) because the bony wedge that has been avulsed from the posterior portion of the tibia remains attached to the posterior tibio fibular ligament and reunites firmly with the tibia after complete reduction Redisplacement in spite of good reduction following widening of the mortise always results from too short a period of immobilization Fixing the distal fibula to the tibia with screws should not be done because every screw that traverses a joint sooner or later breaks (figs 2726 b 2727 a)

2 The tibio fibular space appears wider (fig 2628) in a roentgenogram of a normal ankle taken with an inward rotation of more than 30° than in roentgenograms taken with a lesser degree of inward rotation (fig 2627) Under such circumstances the diagnosis of disruption of the mortise is often erroneously made and the joint stabilized with screws In figure 2727 the distance between the medial malleolus and the talus is increased by 2 mm



2719 March 13 1953 2720 December 31 1927

Fig 2719 Interposition of the tendon of the tibialis posticus tendon between the joint surface of the tibia and the medial malleolus After the tendon was withdrawn reduction was easy

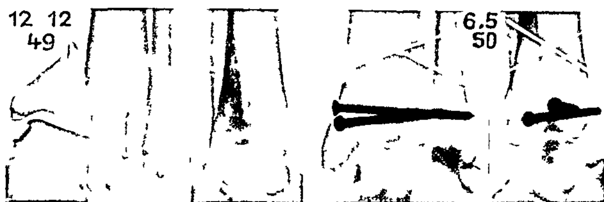
Fig 2720 – Open supination external rotation fracture stage 4 according to Lauge Hansen Torsion fracture of the lateral malleolus at the level of the joint The medial malleolus is intact The foot is dislocated laterally by its full width rotated outwards by 90° Behind the lateral malleolus is a small bony fragment that corresponds to the posterior surface of the tibia The medial malleolus lay free in the large burst wound like in fig 2739 After exact excision of the wound and suture of the skin reduction was attempted which was unsuccessful even in the screw traction apparatus Subluxation of 3 mm remained on the medial side of the joint Therefore the joint was exposed from posterolaterally The tendon of the tibialis posticus was found interposed between the lateral fracture surface of the tibia and the lateral malleolus After withdrawal of the tendon reduction was readily accomplished Temporary cast for two weeks followed by a short leg walking cast for 10 weeks Ankle joint movable through half its normal range at re examination

The joint between the tibia and the fibula was intact In spite of this it was fixed with a screw (fig 2727 a) supposedly to avoid a later divergence of the malleoli The upper screw was already broken by the fifth month

In figure 2724 is pictured a supination external rotation fracture of both malleoli in which the malleoli have retained their normal relationship to the talus In spite of this, however a complicated osteosynthesis was carried out because of a supposed disruption of the ankle mortise but without complete reduction

3 Marginal fractures from the posterior surface of the tibia or posterior wedges that involve less than one third of the lower joint surface of the tibia are often secured with screws even though they are stable after reduction and always unite (figs 2722, 2722 a)

4 It is superfluous to fix the lateral malleolus with wire loops or intramedullary nails (fig 2722 a) if the fracture dislocations of the malleoli are well reduced As a rule osteosynthesis should only be carried out for the medial malleolus



2721 December 12 1949 2721 a May 6 1950

Fig 2721 —Open supination adduction fracture stage 3 according to Lauge Hansen Incurred by a 29 year old woman in jumping from a table The lateral malleolus is torn off transversely below the level of the joint The medial malleolus is split off longitudinally The talus is dislocated medially by its full width and cranially by 1 cm The medial edge of the tibial fracture is impressed A 2 cm wound over the lateral malleolus Proximal to this skin is stretched and white *Treatment* Meticulous wound excision skin suture and reduction Then exposure of the medial malleolus At the medial edge of the tibia numerous small bone splints and cartilage bits have been sheared off and lie between the two fragments They are removed Then the medial malleolus is fixed with two screws *One of them is too long and extends through the tibio fibular joint* After suture of the skin temporary long leg bed cast for two weeks followed by a short leg walking cast for 8 weeks

Fig 2721 a —Same case after 5 months Both fracture sites show bony union in good position *Minimal thickening of the ankle Ankle joint mobility from 80°—115° as compared to 70° to* 125° on the right Walks without pain and without limp The screws were now removed



2722 2722 a

Fig 2722 —Supination external rotation fracture stage 4 according to Lauge Hansen Torsion fracture of the lateral malleolus at the level of the joint Avulsion and shearing off of a small dorsal wedge of the tibia The medial malleolus remains intact

Fig 2722 a —Same case *The small dorsal wedge was fixed by means of a screw* — elsewhere — and the only slightly displaced lateral malleolus was fixed with an intramedullary nail and a wire loop These three fixations are superfluous because the position in this type of fracture can be readily maintained by a non padded short leg walking cast after reduction

Faulty Technique in the Operative Treatment of Fresh Malleolar Fractures

The following types of faulty technique are found

1 Osteosynthesis without exact reduction
2 Utilization of too much metal
3 Too extensive stripping of the soft tissues from the fragments
4 Transfixion of the tibiofibular joint with wires and screws
5 Insertion of screws through the ankle joints
6 Insertion of screws too close to the joint

1 Exact reduction is an essential requirement for a satisfactory result Fixation without exact reduction hinders subsequent attempts at manual reduction In figures 2623 a, 2725 b and 2730 such cases are presented It must be added that the operations were superfluous in all four cases

2 Utilization of too much metal Some bones look like metal collections after surgery (figs 2722 a 2723 a 2724 a 2726 a, 2727 a) In some cases even more metal has been used Nuts and bolts, washers and plates are used as if heavy framework were being erected in which large beams must be held together Entirely different mechanical and biologic conditions are present in fractures The fragments and torn ligaments will reunite in time of 3 to 4 months if reduced early and accurately and if immobilized uninterruptedly in an unpadded cast Internal fixation is then unnecessary

3 Too extensive exposure of the bones If the periosteum is widely stripped from the bone necrosis and signs of irritation and later atrophy of cartilage develop as shown in figure 2725 c

4 Transfixion of the tibiofibular joint with wires or screws The cartilage of this not unimportant joint is thus damaged and arthrosis results as shown in figures 2725 c 2726 b and 2727 a Besides this every screw and every wire that traverses a joint will sooner or later break Figure 2721 a shows how one of two screws that was used to stabilize the medial malleolus superfluously passed through the tibiofibular joint

5 Introduction of screws into the ankle joint If a screw traverses the ankle joint (figs 2728 a, 2729) cartilage damage and later arthrosis result

6 Insertion of screws too close to the joint If metal is situated too close to a joint signs of irritation and arthrosis follow if it is not removed early In the patient shown in figure 2753 a spastic flat foot developed and persisted until the removal of the screw

FRESH OPEN FRACTURES OF THE MALLEOLI

Mechanism Open fractures of the malleoli may occur indirectly when the displacement is so extreme that the skin bursts (figs 2731—2744) They may also result from a direct impact, e g of a motorcycle The skin is then severely lacerated and ground in with dirt the bones are not significantly displaced

Treatment Wound excision If the patient arrives for treatment in the first 8 to 10 hours the wounds are carefully excised under local anesthesia according to the rules listed in Vol I, pp 149—174 Under the protection

of the antibiotics this time can sometimes be stretched to 24 hours All torn remnants of ligaments and capsule and the bone and cartilage surfaces with ground-in dirt should be carefully removed

Osteosynthesis with Crossed Wires After the excision of the wound the fracture dislocation is reduced and X-rays are taken If these show good position in both planes, the medial malleolus is stabilized with two percu



2723 2723 a 2724 2724 a

FIG 2723 —Pronation external rotation fracture stage 3 Lauge Hansen adds (1) Fractura malleoli medialis (2) Separation of the lig malleoli lat anterius lig inteross with a fragment of the venterolateral corner of the tibia (3) Fracture of the fibula proximal to the syndesmosis

FIG 2723 a —Same case after internal fixation with incomplete reduction *elsewhere* Lateral subluxation remains as can be seen by the fact that the joint surface of medial malleolus lies in the longitudinal axis of the shaft of the tibia instead of at an angle of 20° to 30° The medial prominence of the medial malleolus which can be well seen in fig 2725 is absent The screw for the medial malleolus would have been suitable in the presence of interposition following accurate reduction Fixation of the fibula to the tibia with a bolt and nut is *mechanically superfluous and is harmful because the wire traverses the joint*

FIG 2724 —Supination external rotation fracture stage 4 according to Lauge Hansen Compare with fig 2611 c Torsion fracture of the lateral malleolus at the level of the joint Avulsion of the medial malleolus with lateral subluxation and valgus

FIG 2724 a —Same case following internal fixation with two plates a bolt and two nut *elsewhere* In this type of fracture open reduction is superfluous because interposition is not present The joint is not reduced after the operation Lateral subluxation remains The fracture surface of medial malleolus overrides the joint surface of the tibia by one half of its width The medial malleolus is forced laterally by the medial plate and is therefore tipped so that its joint surface lies in the longitudinal axis of the tibia rather than at an angle of 20° to 30° The nuts are pulled too tight and force the talus out of the ankle mortise so that it is tipped as in fig 2725 b The upper joint space is therefore wider medially and disappears laterally According to the description accompanying the roentgenograms the indication for operation was the presence of a disruption of the ankle mortise This however was not present Such an operation is harmful

taneous crossed wires according to the technique outlined on page 1951 (figs 2733 a 2734 a) This protects the joint against redisplacement Internal fixation of the lateral malleolus is not necessary

Roentgen Control After insertion of the two crossed wires X-rays are taken in both planes with internal rotation of 15° to 20°

Suture of the Skin Without Tension After careful wound excision accurate reduction of the fracture dislocation and after X-rays have been taken and

internal fixation carried out soft rubber drain is led out through a stab wound and the skin is sutured without tension No sutures or ligatures are buried under the skin If the wound is older than 12 hours it may be sutured only if there is no evidence of infection

Immobilization After suture of the skin a non padded temporary long leg bed cast is applied in the manner described on page 1920 and is imme

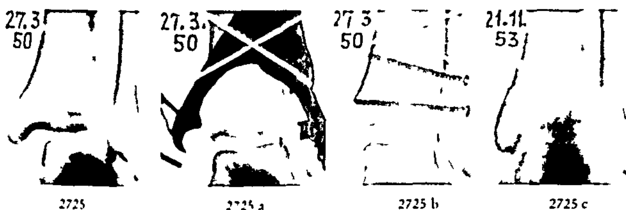


FIG 2725 Lauge Hansen writes Pronation external rotation fracture 3° 4° (Lateral roentgenogram is absent and the entire leg is not included on the film A fracture must be present in the proximal portion of the tibia) 1 Tear of the medial ligament in place of a fracture of the medial malleolus 2 Tear of the lig mall lat anterius and lig inteross 3 Fracture of the proximal end of the fibula 4 Fracture of the posterior tibial lip Incurred by a 50 year old official in a fall while skiing

FIG 2725 a Same case during operation Because repeated attempts at closed reduction were unsuccessful both malleoli were exposed and were pressed together with a clamp The talocrural joint space is much wider than normal showing that the talus has been forced out of the ankle mortise

FIG 2725 b—Same case Tibia and fibula are fixed together with two screws They have been pulled too tight so that the talus is forced out medially The screws were then removed A temporary cast was applied without internal fixation for two weeks followed by a short leg walking cast for an additional fourteen weeks At conclusion of treatment after 5 months the ankle mortise was closed and the joint was clinically sound but definitely thickened Mobility from 70° to 105° as compared to 70° to 120° right

FIG 2725 c Same case after 3 years and 8 months The joint space has disappeared The interosseous ligament is replaced by bone The ankle joint is immobile and painless The fact that the joint become solid without screws shows that the operation was superfluous That it was harmful is shown in the roentgenogram taken at follow up examination The cartilage was damaged by the intervention and the joint therefore become ankylosed

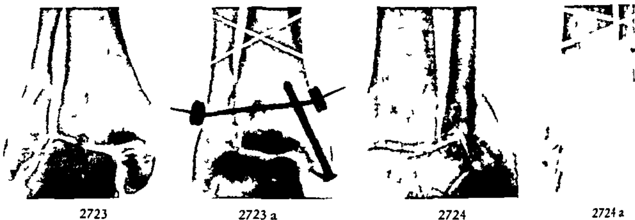
diately split through the last thread and windowed over the wound and the drain

Covering of Skin Loss If a skin defect is present it should be covered by pinch grafts (Vol I/figs 157 158) or a split graft after application of a cast

Skin Necrosis If skin necroses occur especially at the wound margins they should not be excised even if they require 1 to 2 months before they separate as otherwise the bone would be exposed and a low grade joint infection may still appear weeks later Dry necroses usually separate after a few weeks Epithelialization or the development of granulation tissue has usually occurred by this time If the exposed bone and tendons are covered

of the antibiotics this time can sometimes be stretched to 24 hours All torn remnants of ligaments and capsule and the bone and cartilage surfaces with ground-in dirt should be carefully removed

Osteosynthesis with Crossed Wires After the excision of the wound the fracture dislocation is reduced and X-rays are taken If these show good position in both planes, the medial malleolus is stabilized with two percu



2723 2723 a 2724 2724 a

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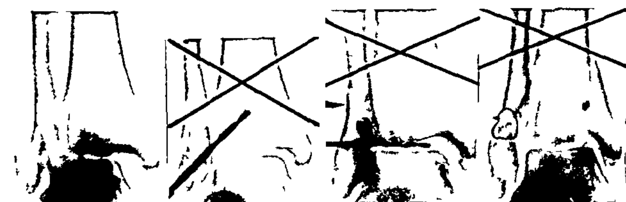
Suture of the Skin Without Tension After careful wound excision, accurate reduction of the fracture dislocation and after X-rays have been taken and

the application of the cast Applying the walking iron and further treatment are carried out in a similar manner as for closed malleolar fractures (see pages 1928—1932)

Application of the Lower Leg Walking Cast in the Presence of Skin Damage If skin necroses appear a walking cast may not be applied until the wound has almost or completely healed with or without a skin graft

Duration of Immobilization If displacement has been minimal the cast can be removed after 10 weeks In severe fracture dislocations as shown in figures 2731—2744 immobilization must be continued 4 to 5 months

Exercises and further care are carried out as for closed malleolar fractures (pp 1930—1932)



2728 June 8 1951 — 2728 a June 11 1951 — 2729 February 29 1950 — 2730 September 10 1950

FIG 2728—Supination external rotation fracture stage 4 Torsion fracture of the lateral malleolus at the level of the joint and complete tear of the deltoid ligament Lateral subluxation of 8 mm as in fig 2718 a The lateral malleolus is displaced posteriorly and laterally and is caught on the fibular shaft It was possible to reduce this only surgically

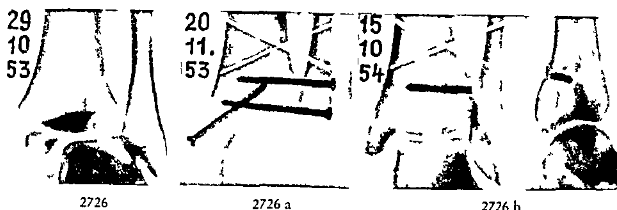
FIG 2728 a—Same case The lateral malleolus was fixed with a screw The drill traverses the lateral side of the ankle joint as well as the joint between the tibia and fibula If the malleolus would not have maintained its position without internal fixation it would have been better to fix it with a wire loop as in fig 2718 b

FIG 2729—Reduced supination external rotation fracture stage 4 in which the drill is too far distal and has penetrated the joint

FIG 2730—Supination adduction fracture stage 2 in which there is also medial subluxation of the talus The mortise is therefore too wide A wire loop was placed through the fibula although the fracture dislocation was not reduced

Questions We Should Ask Ourselves in Order to Avoid Failures in the Treatment of Fresh Open Fractures of the Malleoli

1 Have I carefully excised the wound under local anesthesia in the first 8 to 10 hours according to the rules given in Vol I/pp 149—174?
2 Have I reduced the fracture dislocation after exact wound excision?
3 Have I obtained roentgenograms in both planes with the foot rotated 15° to 20° inward after the reduction?
4 Have I after good reduction fixed the medial malleolus with two percutaneously introduced wires (figs 2733 a 2734 a 2826)?
5 Have I avoided internal fixation of the lateral malleolus whether the fracture was of the pronation or the supination type?



2726 2726 a 2726 b

FIG 2726 —Pronation external rotation fracture stage 4 according to Lauge Hansen Incurred by a 23 year old mason who fell from a 1 M high scaffold Avulsion of the medial malleolus disruption of the tibiofibular joint torsion fracture of the tibia at its upper end (not included in the reproduction) and avulsion of a small lamella of the posterior surface of the tib a

FIG 2726 a —Same case In order to avoid a later separation of the well reduced ankle mortise the fibula was fixed to the tibia with two screws and a screw was placed through he medial malleolus Then a temporary cast was applied for two weeks followed by a short leg walking cast for an additional 12 weeks

FIG 2726 b —Same case after a year The lower two screws were removed after four months because the upper one was broken Part of the broken piece remains in the tibia Periosteal bone formation over this screw fragment between tibia and fibula Ankle thickened Pain af er prolonged walking Mobility 85° to 115° as compared to 75° to 130° right



2727 March 29 1953 2727 a September 11 1953

FIG 2727 —Impaction fracture sustained n plantar flexion with shearing off of a 20 mm wide 40 mm high dorsal tibial wedge the base of which includes only one third of the joint surface of the tibia with suggestion of dorsal subluxation Lateral subluxation of 2 mm Sustained by a 41 year old 167 cm tall 76 kg landlady who slipped on a stair Although the fracture was easily reduced and was stable two screws were used to fix the dorsal wed e and the fibula to the tibia presumably to avoid a separation of the syndesmosis between tibia and fibula Temporary split shor leg cast for two weeks followed by a short leg walking cast for six weeks

FIG 2727 a —Same case after 5½ months The two frontal screws become loose The screw track is enlarged Both screwsare broken at the joint space between tibia and fibula

with granulation tissue fairly large wound areas can be covered secondarily with pinch grafts

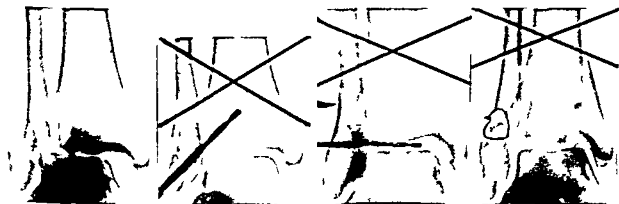
Application of the Lower Leg Walking Cast It the wound has healed without incident, a short leg walking cast is applied in the third week in the manner described on page 1928 Sutures should be removed one day before

the application of the cast Applying the walking iron and further treatment are carried out in a similar manner as for closed malleolar fractures (see pages 1928—1932)

Application of the Lower Leg Walking Cast in the Presence of Skin Damage If skin necroses appear a walking cast may not be applied until the wound has almost or completely healed with or without a skin graft

Duration of Immobilization If displacement has been minimal the cast can be removed after 10 weeks In severe fracture dislocations as shown in figures 2731—2744 immobilization must be continued 4 to 5 months

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2728 June 8 1951 — 2728 a June 11 1951 — 2729 February 29 1950 — 2730 September 10 1950

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4 Have I after good reduction fixed the medial malleolus with two percutaneously introduced wires (figs 2733 – 2734 a 2828)?
5 Have I avoided internal fixation of the lateral malleolus whether the fracture was of the pronation or the supination type?



2731 September 26 1935

FIG 2731 —*Open* pronation abduction fracture stage 3 with complete lateral dislocation of the *foot and soiling of the bone and cartilage* *Sustained by a 51 year old laborer in a fall from* a ladder during which he caught his foot in a rung so that the rung sheared off The anterior picture shows a bending fracture of the lateral malleolus and avulsion of the anterior part of the medial malleolus Both have maintained their relationship to the talus In the lateral picture the overlapping of the talus and the tibia can be seen *Treatment* meticulous wound excision and suture of the skin only after insertion of a drain Blood vessel ligatures and buried sutures were avoided The cast was immediately split Followed by short leg walking cast for 6 months



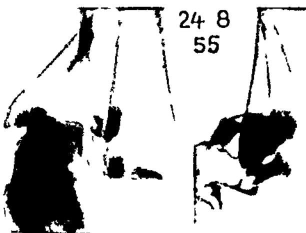
2732 July 16 1938

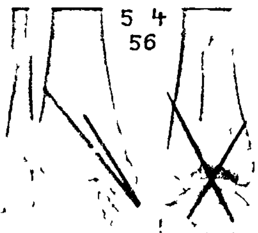
FIG 2732 —Same case after three years The lateral malleolus has healed with 2 mm lateral displacement Pseudarthrosis of the medial malleolus At present we would fix the medial malleolus with 2 percutaneously inserted crossed wires Then immobilization of 4 months would be sufficient Partial subluxation of 2 mm The joint space is of normal width No arthrosis Joint laterally stable Plantarflexion reduced by 10° Dorsiflexion normal Walks well

6 Have I used a soft rubber drain after the introduction of the crossed wires?

7 After the insertion of the drain have I closed the wound by suture of the skin only without burying ligatures or sutures?

8 In wounds older than 12 hours have I sutured the wound only if it was clean and not smeary?

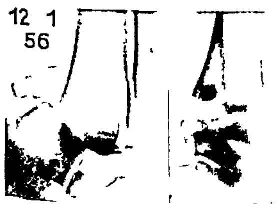


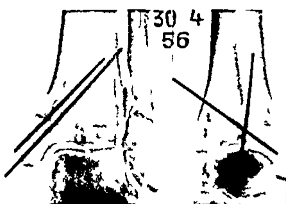


2733 August 24 1955 2733 a April 5 1956

FIG 2733 – *Open* pronation external rotation fracture stage 4 The medial malleolus is avulsed Torsion fracture of the fibula 8 cm above the tip of the malleolus Complete dislocation of the talus laterally and 2 5 cm cranially The badly dirtied tibia projects from the wound as in fig 2739 The lower joint surface shows several cracks Incurred by a 51 year old cleaning woman who fell 2 M from a ladder *Treatment* Exact excision of the wound and cleaning of the bone Reduction of the fracture and fixation of the medial malleolus with two crossed wires Temporary split long leg bed cast for 3 weeks followed by a long leg walking cast for an additional 11 weeks

FIG 2733 a – Same case after 7 months The fracture dislocation has united in good position The tibio fibular joint is closed Form of the ankle joint normal without swelling but with mild cyanosis Still limps Ankle joint mobile from 85⁰ to 115⁰ as compared to 75⁰ to 125⁰ left Motion in the talo calcaneal joint limited by two thirds





2734 January 12 1956 2734 a April 30 1956

FIG 2734 – Open supination adduction fracture stage 2 Sustained by a 48 year old farmer who was struck on the inner side of the left lower leg by a falling log Bending fracture of the tibia with a 2 5 cm medial bending wedge 5 cm above the ankle joint The medial malleolus is sheared off vertically with varus position of 40⁰ Over the fracture site of the fibula are two transverse wounds 2 cm and 3 cm in length respectively separated by a 5 mm bridge of skin Skin over the involved area severely damaged *Treatment* Excision of the wound reduction of the fracture and percutaneous fixation of the medial malleolus with two crossed Kirschner wires Temporary long leg bed cast which is immediately split and windowed over the wound for three months followed by a long leg walking cast for an additional two months Dry necrosis of the skin developed in the area of the severe skin damage This involved an area of 10×5 cm and began to loosen itself after 5 weeks A 1×2 cm area of the lateral malleolus is exposed and in several places the peroneus tendons are exposed Two weeks later these areas are covered with clean granulations After 9 weeks this area which now measures 2×3 5 cm is covered by pinch grafts which take well After 3 months a short leg walking cast is applied

FIG 2734 – Same case after 4 months at removal of the short leg walking cast Good position in both planes Considerable decalcification Fracture line of the fibula still plainly visible therefore application of another short leg walking cast for an additional 7 weeks Follow up examination 6 months after the injury shows a soft scar Ankle joint 85⁰ to 115⁰ as compared to 75⁰ to 120⁰ on the sound side Gait painless without a cane





2735 July 9, 1937 2736





2737 July 15 1937 2738

FIGS 2735 2736 — *Open* fracture with complete dislocation of the foot posteriorly medially and proximally In the A P projection the foot is seen to be externally rotated 90° In the lateral projection of the tibia the foot is seen from in front Both malleoli are in normal relationship to the talus

FIGS 2737 2738 — Same case after 1 year Bony union in good position Ankle joint space narrowed Able to work again as engineer At present we would fix the medial malleolus with two crossed wires

9 Have I applied a temporary long leg cast after suture of the skin?

10 After application of the temporary long leg cast, have I obtained new roentgenograms in both planes with the leg rotated 15° to 20° inward?

11 Have I removed the cast, repeated the reduction, replaced the long leg cast and repeated the X-rays if the films showed an unsatisfactory position? Have I repeated this until the position was satisfactory?

12 Have I immediately split the long leg cast through the last thread along a cord placed on the skin prior to application of the cast and windowed the cast over the wound and the drain if roentgenograms showed good position?

13 Have I covered skin defects with pinch grafts (see Vol I/figs 157, 158) or a split thickness skin graft?
14 Have I removed the drain in 24 hours?
15 Have I removed the sutures not earlier than the third week (the day before the change of cast)?



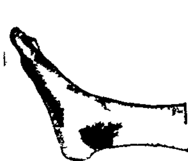
2739 July 9 1937



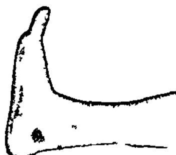
2740 July 15 1938



2741



2742



2743 July 15 1938



2744

Fig 2739 —Photographs corresponding to figs 2735 2736 *Open* fracture dislocation of both malleoli sustained by a 39 year old man who was struck and dragged 10 M by an auto while he was on the sidewalk 10 cm transverse tear on the medial side of the ankle joint The lower end of the tibia projects far out of the wound and is badly soiled Pulse easily palpable After painstaking excision of the wound and reduction a drain was inserted and the skin alone was sutured without burying sutures or ligatures No tetanus or gas gangrene antitoxin Plaster cast that was immediateley split After 6 weeks a walking cast that was removed 4 months after the injury

Figs 2740—2744 —Photographs corresponding to figs 2737 2738 and comparison photograph to fig 2739 after 1 year Healed with soft freely moveable scar Ankle joint slightly thickened Flexion and extension each limited by 10° Prolonged walking possible

16 Have I avoided debridement of skin necroses but rather waited until they separated by themselves in order to avoid opening the joint?
17 Have I in uncomplicated wounds applied a short leg walking cast in the third week or in the presence of skin necrosis as soon as the wound was completely or almost completely closed?

18 Have I in the presence of dry or moist skin necrosis applied pinch grafts or a split graft as soon as the granulations were clean?

19 Have I continued immobilization for 10 to 20 weeks depending on the extent of the original displacement?

Results of Treatment of Fresh Open Malleolar Fractures

Ehalt[1] described the 23 cases that were treated by us in the nine years between 1926 to 1934 He personally re-examined *all* of the patients clinically and radiologically after an observation period of 2 to 9 years He recorded the results in tables including the age, occupation manner of injury, side, type and location of fracture, treatment, length of time required for healing duration of disability, shortening, manner of wound and of fracture healing fistulae, sequestra, position of fragments, mobility of joints, associated injuries, and disability payments In addition to this roentgenograms and photographs were presented of all patients whose wounds did not heal per primam or who drew disability payments

Fatalities 22 of 23 patients were living at the time of re examination A 55 year old man died of a coronary thrombosis on the 41st day after the accident after having been discharged from the Accident Hospital The wound had healed uneventfully (figs 2656—2658) *No one died of infection*

Amputations In spite of the severity of the injury (figs 2720, 2731—2744) primary amputation was not done Nor was secondary amputation necessary because of infection or for other reasons

Wound Infections Only a single case developed a late secondary infection of the joint following skin necrosis over the outer malleolus in a supination fracture

Spreading infection never occurred

Erysipelas never occurred

Metastatic suppurative pneumonia never occurred

Sequestrations were not found at the follow up examination

Fistulas never occurred

Ulceration in scars never occurred

Flexion contracture at the ankle did not occur

Orthopedic braces were never required

The average duration of disability was 129 days

Mobility of the ankle joint In 18 cases (77 4%) mobility was free, in 2 cases it was restricted by 1/4 in one case 1/3, and in one case by 1/2 Ankylosis with good position resulted in one case

Mobility in the subtalar joint was free in 18 cases (81 9%) limited by 1/2 in one case In three cases the subtalar joint was immobile caused in two cases by fibrosis and in one case by bony ankylosis

Mobility of the toes was normal in all cases

Vascular disturbances in the sense of cyanosis or swelling did not occur

[1] Ehalt W Die Behandlung der offenen Brüche der langen Röhrenknochen mit Einschluß der Behandlungsergebnisse Vienna Maudrich 1938

— Tratamiento de las fracturas abiertas Barcelona Editor Labor 1940

The *cosmetic result* was good in all cases In no case was there a lateral displacement or angulation In several cases the ankle was slightly thickened

Disability Pensions Of the 23 patients 16 were insured Three of them had severe concomitant injuries and therefore drew disability compensation Of the 13 patients that had no concomitant injury only 2 (15 4%) drew permanent disability pensions whereas none of the remaining 11 drew a permanent pension

On pages 226 and 227 of Ehalt s book the results of authorities such as Scheffler, Stechmann and Felsenreich are presented

INFECTED FRACTURES OF THE MALLEOLI

If open fractures of the malleoli are not admitted until 8 to 10 hours after the injury, the torn and dirt-laden tissue is removed according to the rules given in Vol I/pp 179—198 The wound itself however must not under any circumstances be sutured but must be left wide open After the reduction an unpadded long leg cast is applied, split and appropriately windowed The leg is placed on an oblique splint The wound is left exposed With adequate and uninterrupted immobilization in a temporary long leg cast the infection only seldom progresses Incisions are seldom necessary

When the wounds are healed or almost healed an unpadded short leg cast is applied and windowed over the wound The edges of the window are sealed off with zinc oxide ointment A sterile gauze sponge is fitted into the window and pressed down firmly It is sprinkled with boric acid powder to suppress the odor If not enough gauze is used or if the bandage is not applied tightly enough, window edema results and the edges of the window cut into the skin If the pus has free egress the cast need not be windowed

Duration of Immobilization Immobilization must be continued 3 to 6 months depending on the original displacement Occasionally some mobility remains If however the entire cartilaginous surface is destroyed a painless ankylosis results This is preferable to a painful and only slightly moveable joint

If the plaster is removed too soon a flexion contracture or a pes equino-varus will develop as in figures 2774 2776 If the cast does not extend to the tips of the toes and no sponge rubber is placed under the toes hammer toes may develop

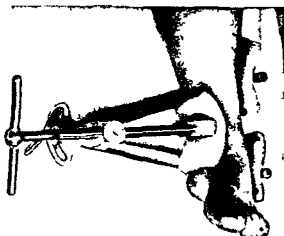
OLD MALLEOLAR FRACTURES AND MALUNITED MALLEOLAR FRACTURES

Even the smallest displacement visible in the roentgenogram can produce lasting disturbances because the joint surfaces are no longer congruent and therefore grind on each other Arthrosis results after years the severity of which is related to the amount of displacement (figs 2675—2677) The ankle joint remains painful Severe valgus deformity of the ankle will lead to talipes valgus and flatfoot Varus of the ankle will lead to pes cavus or club foot Anterior or posterior dislocation may be followed by ankylosis after several years

CONSERVATIVE TREATMENT OF OLD MALLEOLAR FRACTURES

In the first three months displacements in the frontal plane (lateral or medial displacement) can often be corrected by manipulation while displacements in the sagittal plane (posterior or anterior displacement) can no longer be corrected conservatively after two or three weeks

In the first weeks the fracture can be mobilized with both hands or over a padded wooden wedge by increasing the displacement Then reduction is carried out as in fresh fractures (see p 1919)



2746 July 6 1931

Fig 2746 —Reduction of an old malleolar fracture with the Phelps Gocht osteoclast Padded with heavy felt

If reduction is not successful because the fragments can no longer be mobilized the displacement is increased and then reduced with Phelps-Gocht s osteoclast (fig 2746)

When the roentgenograms show good position in both planes, a temporary short leg bed cast is applied Further treatment is carried out as for fresh malleolar fractures (see pp 1927—1932)

Operative Treatment of Old Pronation Fractures

Old pronation abduction fractures or pronation external rotation fractures which only show an outward displacement can be reduced surgically in the first two years after the injury if the roentgenograms show that the cartilage is intact

Technique of Operation Under general anesthesia and in a bloodless field maintained by tourniquet the lateral malleolus is exposed subperiosteally through a longitudinal incision It is then divided with a chisel through the old fracture site in an oblique-frontal plane Exuberant callus is removed The medial malleolus is exposed with a transverse incision and also divided through its old fracture site *If only the lateral malleolus is fractured* (fig 2747) the inner malleolus is exposed with an anterior longitudinal incision and the scar tissue between the talus and the medial malleolus is removed Then the

foot is pulled laterally in order to free the ligaments and capsule and then pressed inwards in order to reduce it When one has the impression that the foot is reduced, X-rays are obtained in both planes with an inward rotation of 15° to 20° If these do not show good position the foot is again forced strongly laterally and then medially until the roentgenograms show good position

Osteosynthesis of the Medial Malleolus with Crossed Wires When the position is satisfactory as seen in the X-rays the medial malleolus is fixed with two percutaneously introduced crossed wires as in open fractures (see p 1960)

We formerly did not use osteosynthesis but achieved good results (fig 2752 a) Simple osteosynthesis with two crossed wires is preferable, because without it redisplacement can occur in a split temporary cast

Osteosynthesis of the lateral malleolus with screws, intramedullary nails and wires is not only superfluous but harmful In figure 2753 a the lateral malleolus was fixed with a wire suture and the tibio-fibular joint was transfixed with a screw even though there was no disruption of the ankle mortise As a result of irritation from the screws which were introduced near the ankle joint a spastic flatfoot resulted which lasted until the screws were removed

Further treatment is carried out as for open fractures (see pp 1960—1963)

Operative Treatment of Old Supination Fractures

As in old pronation fractures operation may be carried out only if the joint space is maintained Before operation a tracing is made on transparent paper as in old tibial fractures (figs 2576 b, 2581 a, 2581 c) A transverse scissors cut is made through the lateral malleolus from laterally at joint level and through the joint space from medially so that 2 mm of paper remain intact in the region of the tibiofibular joint When the foot portion is then abducted the outer malleolus becomes superimposed over the fibula and the superimposed wedge represents the bony wedge that must be removed from the lateral malleolus

The operation is carried out under general or spinal anesthesia in a bloodless field maintained by a tourniquet The lateral malleolus is subperiosteally exposed with a lateral longitudinal incision Then the bony wedge whose size has been previously determined is chiseled out After closure of the wound with two towel clips the medial malleolus is exposed with an anterior longitudinal incision and divided in the old fracture line namely in the sagittal plane Since new bone has formed between the tibia and the medial malleolus a sagittal lamella of bone 1 to 2 mm thick is chiseled from the tibia (fig 2750) Then it is usually easy to reduce the fracture and the dislocation Then the lateral wound is reopened and the fracture site inspected to see if the position of the lateral malleolus is satisfactory

X-ray Control If the films show satisfactory position the medial malleolus is fixed with two percutaneously introduced crossed wires When the roentgenograms thereupon show good position the skin is closed

Further treatment follows as for open malleolar fractures (see pp 1960 to 1969)



2747
October 6 1927



2748
February 1 1928



2749
September 26 1929



2750
January 20 1930



2751
October 2 1931

Fig 2747 —Old supination external rotation fracture stage 4 Fracture of the lateral malleolus with almost complete dislocation of the foot outward 8 months after the injury This man was treated *elsewhere* without any immobilizing bandage with massage and passive movement

Fig 2748 —Same case 4 months after operation Under spinal anesthesia the lateral malleolus was divided with a chisel at the old fracture site After closure of the skin the foot was manipulated by means of the Schultze redresseur During this maneuver the medial malleolus was sheared off and displaced medially The talus is in its proper place The joint space is narrowed The ankle joint is movable through half its normal range Could ski 6 months after operation

Fig 2749 —Supination adduction fracture of both malleoli 4 months after injury 36 year old man Healed in marked varus position Treated *elsewhere* by 4 weeks immobilization in maximal supination of the forefoot Then massage passive motion and ultraviolet light

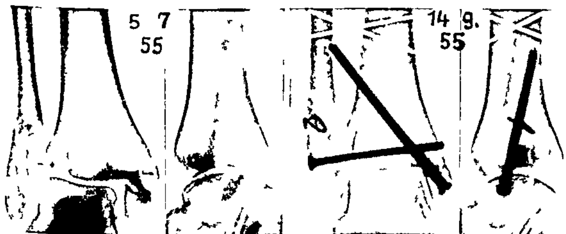
Fig 2750 —Same case 4 months after operation Under spinal anesthesia a wedge *osteotomy* with a lateral base was carried out on the lateral malleolus Then the medial malleolus was chiseled off in a sagittal plane and a 2 mm lamella removed from the tibia Thereupon reduction was easily carried out Walking cast for 10 weeks in which he was able to walk well 1 week after operation Gait normal 4 weeks after removal of cast all movements were possible through their normal range

Fig 2751 —Same case after 1 year The fracture lines have been obliterated by bony union Fracture line visible only along the cartilaginous surface of the tibia Joint space of normal width Able to walk without disturbance

2752 January 18 1929 2752 a February 24 1936

Fig 2752—5 month old supination external rotation fracture of both malleoli healed with lateral subluxation Incurred by a 35 year old woman who slipped on a stair Talus subluxated 8 mm laterally and in valgus position Both malleoli healed with oblique axis Ankle mortise intact Marked decalcification Treated *elsewhere* in plaster for 3 weeks followed by manipulation of fragments and plaster immobilization for 14 days Then massage passive motion heat ultraviolet light and blue light Because she continued to have pain on walking and the roentgenogram showed marked decalcification the diagnosis of traumatic tuberculosis was entertained and bed cast in a sanatorium was recommended

Fig 2752 a—Same case 7 years after osteotomy of both malleoli and reduction of the subluxation Followed by a temporary cast for 8 days and short leg walking cast for an additional 11 weeks She was able to walk without pain 10 days after operation 4 weeks after removal of the cast the joint was freely movable Is able to walk without disturbance Both malleoli healed in good position Talus located normally in the joint Normal calcium content No arthrosis Joint sound and movable through its full range Has no complaints



2753 2753 a

Fig 2753—4 month old supination external rotation fracture Incurred by a 22 year old woman sales clerk who slipped on ice and fell Torsion fracture of the lateral malleolus at joint level and avulsion of the medial malleolus with lateral subluxation of the foot Treated *elsewhere* in a temporary cast for three days followed by a short leg walking cast for 8 weeks Roentgenogram only prior to reduction none after reduction Foot in valgus position Gait painful Mobility 80° to 120° as compared to 80° to 130° on the left *Treatment* Under general anesthesia and tourniquet both malleoli were exposed and their fibrous union divided with sharp dissection Thereupon reduction was easily possible The medial and lateral malleoli were fixed with screws and the lateral encircled with a wire loop Both screws are closely adjacent the ankle joint Temporary cast split for 2 weeks followed by a short leg walking cast for an additional 8 weeks

Fig 2753 a—Same case following removal of cast Bony union of both malleoli in good position The screw through the medial malleolus reaches to the fibula and has evoked a periosteal reaction Complains of continued pain A spastic flatfoot had developed Therefore the screws were removed after 5 months At re examination after a year the ankle joint was still thickened Pain on walking Mobility 90° to 110° as compared to 80° to 130° on the left If in this case a cast had been applied following osteotomy and reduction of both malleoli as in the woman pictured in fig 2752 without introducing long screws in the vicinity of the joint the result would probably have been better At present we would have fixed the medial malleolus with two percutaneously introduced crossed Kirschner wires

Operative Treatment of Old Posterior or Anterior Fracture Dislocations

Old posterior (fig 2770) or anterior fracture dislocations should not be reduced surgically after three weeks If major symptoms appear arthrodesis should be performed in these cases (fig 2770) Trojan (see p 1835) in our 1222 fresh and 88 old cases with large dorsal wedge has found that usually severe arthrosis develops if surgical reduction was carried out later than three weeks after the accident

115 NON-UNION OF MALLEOLAR FRACTURES

Non-union occurs chiefly at the medial malleolus Non-union may also occur at the lateral malleolus or at both malleoli

Etiology Non-union may occur in spite of good reduction of the talus if the obstacles described on pages 1952—1953 especially interposition of fascia and periosteal flaps (figs 2707—2714) and torsion or tilting of the medial malleolus (figs 2715, 2716), are not overcome Non union may also follow inadequate reduction of bimalleolar fracture dislocations or inadequate immobilization after satisfactory reduction

Diagnosis *Clinical examination* is carried out in the manner described on pages 1905—1907 Particular attention is paid to stability and tenderness of the ankle since non-unions may be stable or unstable, painful or painless Patients with mobile non-unions usually have pain on weight-bearing, namely, during walking or standing and show swelling of the ankle The malleolus is tender to pressure Stable non-unions are usually painless Pseudarthrosis of the tip of the malleolus without displacement of the talus as a rule produces no symptoms

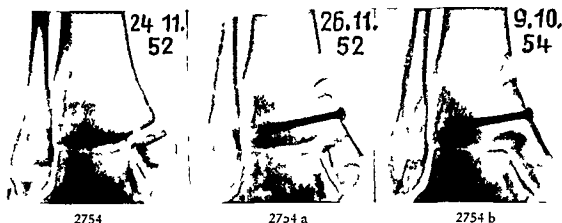
Roentgen Examination Non union of the malleoli can be recognized with certainty only in the roentgenogram The usual roentgenograms should be made first in both planes with an inward rotation of 15° to 20° If indistinct superimpositions appear oblique films with further inward or with outward rotation should be obtained If the injury is older than 6 months and the fracture line is wider than 3 mm a non union (or pseudarthrosis) is present If the fracture line is still visible after 3 to 4 months (figs 2672, 2673) this should be considered as delayed union

X-rays Under Stress In order to determine whether a mobile or a stable non-union is present and in order to determine the extent of mobility, stress roentgenograms with medial or lateral displacement should be obtained

Treatment Painful pseudarthrosis should be treated surgically in a bloodless field maintained by tourniquet and under general anesthesia Painless pseudarthrosis requires no treatment Operation may be carried out only if pulses and reflexes are present A good range of motion of ankle joint and normal width of the joint space are necessary prerequisites for a good result If these conditions are not present it is better to perform arthrodesis

Operation in the Presence of Pseudarthrosis Without Displacement of the Medial Malleolus Utilizing a Reversed Sliding Graft If there is no displacement of the talus or of the medial malleolus, i e if the angle between the joint surface of the medial malleolus and the shaft of the tibia is 20° to 30°

operation can be carried out without further preparation The most certain method is a sliding graft crossing the pseudarthrosis The medial malleolus is subperiosteally exposed with a longitudinal incision Then with a twin circular saw or a chisel a 5×1×0 5 cm piece of bone is cut out of the tibia beginning 3 cm above the pseudarthrosis and ending 2 cm below it It is reversed so that sound bone crosses the pseudarthrosis and the pseudarthrosis is otherwise not touched If this graft lies loosely in its bed it can be fixed with a screw as in fig 2754 Otherwise a few periosteal sutures suffice to hold



2754 2754 a 2754 b

FIG 2754 —8 month old pseudarthrosis of the medial malleolus incurred by a 29 year old miner when a heavy tool fell against his ankle Treated *elsewhere* with compresses for 2 weeks and a short leg walking cast for 9 weeks Then Beck s drilling and short leg walking cast for 12 weeks Presented himself because of pain in the ankle *Treatment* Exposure of medial malleolus under tourniquet and general anesthesia A 6×1 5 cm bone graft 0 5 cm thick was removed from the tibia beginning 4 cm above the pseudarthrosis and extending 2 cm below it This was reversed so that normal bone lay across the pseudarthrosis and was fixed with a screw A temporary bed cast which was split was applied for two weeks followed by a short leg walking cast for an additional 10 weeks At present we no longer use screws for this purpose

FIG 2754 a —Same case after operation The bone graft has been removed from its bed reversed and fixed with a screw The medial part of the pseudarthrosis line is now proximal

FIG 2754 b —Same case after two years The reversed bone graft has healed by bony union The pseudarthrosis line has disappeared Mobility 75° to 115° as compared to 65° to 130° on the left Gait normal No complaints

it in place After the operation a temporary short leg bed cast is applied for two weeks followed by a short leg walking cast for an additional 14 weeks in the manner described on page 1920 The pseudarthrosis will heal in this time It may require 6 to 12 months before the fracture line is obliterated (fig 2754 b)

Operation in Tilting of the Medial Malleolus If the medial malleolus is tilted so that the angle between its joint surface and the shaft of the tibia is less than 20° it must be corrected by excising a medial wedge out of the pseudarthrosis It is then pulled up and held with a hook When the anterior roentgenogram taken in 15° to 20° inward rotation shows good position the malleolus is fixed with two crossed wires as in figure 2716 a A bone-graft is placed across this in the manner described above

Operation in Non-union of the Medial Malleolus following Supination External Rotation Fracture of Both Malleoli with Lateral Subluxation of the Talus First the lateral malleolus is divided in an 'oblique-frontal' plane with a chisel Then the medial malleolus is exposed, divided through the pseudarthrosis, tipped downward, the fibrous tissue of the pseudarthrosis and that between the malleolus and the talus excised and the fracture surfaces are shaped so that they fit Then reduction is usually fairly easy If reduction should not be possible the foot is pushed forcefully outward in order to loosen the capsule and then pressed inward If the medial malleolus now fits satisfactorily, it is held with a hook If a gap remains due to the excision of the pseudarthrosis it must be filled with a small graft taken from the patient's iliac crest or the bone bank A roentgenogram is made with inward rotation of 15° to 20° while the medial malleolus is held with a hook If this shows that reduction was successful the medial malleolus is fixed with two crossed wires (fig 2716 a) A reversed sliding graft is placed across this in the manner described on page 1975 If the osteotomy surfaces of the lateral malleolus do not fit smoothly, the fragments of the lateral malleolus may be sutured with a wire loop as in figure 2718 b Application of the temporary and the walking cast is carried out as described on page 1920

Operation in the Presence of Pseudarthrosis of the Medial Malleolus following Pronation-External Rotation Fracture of Both Malleoli with Lateral Subluxation of the Talus If disruption of the ankle mortise with a gap between the tibia and the fibula is present the ankle joint is exposed with an anterolateral incision The scar tissue between the two bones is excised Then the medial malleolus is exposed with a longitudinal incision and divided through the pseudarthrosis The remainder of the operation is carried out as for pseudarthrosis following supination external-rotation fractures (see above)

Operation in Pseudarthrosis of Both Malleoli This occurs only after supination-external rotation fractures After exposure of the lateral malleolus the fracture surfaces are freshened Further treatment is carried out as described on page 1975

Pseudarthroses of the lateral malleolus without displacement can be treated in the same manner as those of the medial with a reversed sliding graft

Beck's bone-drilling usually is unsuccessful

Fixation of the medial malleolus with a wire loop or a screw is less desirable because the medial malleolus must be more widely exposed This is not necessary for the insertion of crossed wires

Questions We Should Ask Ourselves to Avoid Failures in the Treatment of Non-union of the Malleoli

1 Have I after clinical examination obtained the usual roentgenograms in both planes with the leg rotated inwards 15° to 20°?
2 Have I in questionable cases obtained oblique roentgenograms in further inward rotation or in outward rotation?
3 In the presence of lateral or medial subluxation of the talus have I obtained roentgenograms under stress in order to determine whether the pseud-

arthrosis was stable or unstable and to determine the degree to which the talus can be displaced?

4 Have I carried out the operation only if the patient's general condition was good?

5 Have I carried out the operation only if motion at the ankle was good and the joint space normal?

6 Have I carried out the operation only for painful and unstable pseudarthrosis?

7 In good position of the medial malleolus have I used a reversed sliding graft without freshening the pseudarthrosis?

8 In tilting of the medial malleolus have I excised the scar tissue in the form of a wedge and thus made reduction possible?

9 Have I held the medial malleolus with a hook after reduction?

10 Have I obtained a roentgenogram in the anteroposterior plane with inward rotation of the leg of 15° to 20° while the malleolus was held with the hook?

11 Have I fixed the medial malleolus with two crossed wires if the roentgenogram showed good position (fig 2716 a)?

12 Have I obtained new roentgenograms in both planes with inward rotation of 15° to 20° after the insertion of the two crossed wires?

13 Have I used a reversed sliding bone graft if the X-rays showed good position of the medial malleolus and of the crossed wires?

14 After the operation have I applied a temporary cast for 2 weeks and a walking cast for 14 weeks?

15 In supination external rotation fractures have I first osteotomized the lateral malleolus in an oblique-frontal plane?

16 After dividing the medial malleolus through the pseudarthrosis and after excision of the scar-tissue, have I displaced the foot laterally to stretch the capsule and then medially in order to reduce the subluxation?

17 Have I shaped both fracture surfaces so that they fit well?

18 Have I used a bone graft if a gap resulted between the fragments?

19 Have I carried out the remainder of the treatment as for pseudarthrosis with tilting of the malleolus?

20 Have I sutured the fragments of the lateral malleolus with a wire loop as in figure 2618 b if they could not otherwise be replaced well?

21 In pseudarthrosis of pronation-external rotation fractures with disruption of the ankle mortise have I first excised the scar tissue between the tibia and the fibula and then continued the operation and the aftertreatment as for supination-external rotation fractures?

OPERATIVE TREATMENT OF OLD DISRUPTIONS OF THE ANKLE MORTISE

If one reduces a severe *disruption of the ankle mortise between the tibia and the fibula associated with disruption between the talus and the medial malleolus* (figs 2610 a 2610 b 2611, 2620 2622, 2655) within the first four weeks and immobilizes it uninterruptedly for 16 weeks in a short leg walking

cast, firm union will result in all cases As a rule older fracture dislocations that produce symptoms can be satisfactorily treated only by surgery In these cases tibio-fibular arthrodesis or arthrodesis of the talocrural joint should be carried out Good mobility and normal joint space of the talocrural joint are the prerequisites for a good result following a tibiofibular arthrodesis If the joint space is narrowed or irregular as result of the displaced dorso lateral shearing wedge, arthrodesis of the talocrural joint and not of the tibiofibular joint should be made Overweight of more than 10 Kg is also a contraindication for tibio-fibular arthrodesis

Disruptions of the Ankle Mortise between Tibia and Fibula Only with Fracture of the Medial Malleolus (figs 2611 a, 2611 b, 2621, 2638, 2670, 2675, 2695, 2703, 2733) can be manually reduced as late as 6—8 weeks after the injury After this they can be surgically corrected The operation is carried out as for pseudarthroses of the medial malleolus following pronation-external rotation fractures (see p 1976) If mobility of the ankle joint is sharply restricted and the joint space is narrow arthrodesis of the talocrural joint should be performed

Technique of Operation The operation is carried out in a bloodless field maintained by tourniquet under spinal or general anesthesia The tibio-fibular joint is exposed with a anterolateral longitudinal incision, the scar tissue between the two bones and the cartilage is removed together with the underlying cortical bone The fibula is divided with a chisel several centimeters above the ankle joint in an oblique-frontal plane Then the medial part of the joint is exposed with an anterior incision and freed of scar tissue The joint is then reduced as in a fresh malleolar fracture (fig 2647)

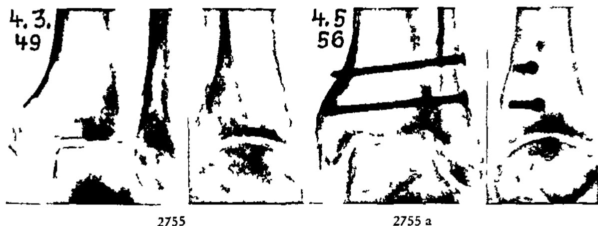
First Roentgen Check and Fixation After the reduction stress roentgenograms are obtained in both planes in inward rotation of 15° to 20° with sharp dorsiflexion at the ankle If they show good position, two screws are intro duced from dorsolaterally to venteromedially through both bones while the ankle is dorsiflexed Dorsiflexion of the ankle is necessary during insertion of the screws because the gliding surface of the talus is broader anteriorly If fixation is carried out with the foot in plantarflexion, the ankle mortise will be too narrow and dorsiflexion will not be possible after healing has taken place If the screws are turned too tightly as in figure 2725 b the talus is forced out of the ankle mortise The transverse joint space appears widened (higher) (fig 2725 b)

Second Roentgen Check After the insertion of the screws new roentgeno grams should be obtained in inward rotation of 15° to 20° and dorsiflexion in order to determine that the joint space is not too wide and not too narrow

Fusion of the Tibiofibular Joint by Bone Grafting Since screws alone cannot give adequate fixation and are likely to break after several months (figs 2726 b 2727 a) the gap in the tibio-fibular joint space that results from the removal of the cartilage and the cortical bone is filled with cortical and spongy bone chips which are obtained from the osteotomy site of the fibula the lower end of the tibia, the head of the tibia the iliac crest, or the bone bank

Duration of Immobilization After the operation a temporary short leg bed cast is applied for 2 weeks It is immediately split through the last thread It is followed by a short leg walking cast for an additional 10 weeks (see pp 1920—1932)

End results Trojan[1] has reexamined the eleven patients operated upon by me in the years 1948—1953 He found that the results were good if the operation was carried out for the proper indications and with good technique



2755 2755 a

Fig 2755—10 week old supination external rotation fracture Incurred by a 60 year old merchant in a fall while skiing According to the roentgenogram accompanying the patient the space between the talus and the medial malleolus after the accident was 17 mm Treated *elsewhere* with a temporary cast for a week and short leg walking cast for 5 weeks Then daily massage passive motion and diathermy Presents himself because he can walk only with difficulty with the aid of a cane and because the leg is markedly swollen up to the thigh Space between medial malleolus and talus 8 mm and between tibia and fibula 6 mm *Treatment* Tibiofibular arthrodesis and temporary bed cast for 2 weeks Then short leg walking cast for 12 weeks

Fig 2755 a—Same case after 7 years Ankylosis between tibia and fibula The screws have not broken Minimal arthrotic lipping at the anterior edge of the tibia Range of motion of ankle 80° to 105° as compared to 70° to 120° on the right Gait painless No swelling

Questions We Should Ask Ourselves to Avoid Failures in the Treatment of Old Disruption of the Ankle Mortise

1 Have I carried out tibiofibular arthrodesis only in disruptions of the ankle mortise with diastasis between the tibia and fibula and with concomitant diastasis between the talus and the medial malleolus?
2 Have I carried out tibiofibular arthrodesis only if there was good mobility of the ankle joint and if the joint space was normal?
3 Have I carried out tibiofibular arthrodesis only if the patient was not more than 10 Kg overweight?
4 After excision of the scar tissue between the tibia and the fibula and between the talus and the medial malleolus have I reduced the subluxation and obtained roentgenograms with the ankle at dorsiflexion and held in reduction

[1] Trojan E Über tibiofibulare Arthrodesen 42 Kongreß der Deutschen Orthop Ges S 284—287 1954

5 Have I carried out fixation with screws with the ankle in the dorsiflexed position?
6 Have I inserted the screws from dorsal laterally to ventral medially?
7 Have I filled the tibiofibular joint space with bone chips after the screw fixation?
8 Have I immobilized the ankle joint in a short leg walking cast for 12 weeks following the operation?



2756 June 19 1935 2757

Fig 2756 2757—2 year old fracture of both malleoli Talus in normal position Lateral malleolus displaced 3 mm laterally Joint space between talus and lateral malleolus is thus widened while that between talus and tibia is narrowed and is irregular in its lateral portion Mobility 15° Swelling of the ankle joint Continuous severe pain on walking and standing Treated *elsewhere* by plaster cast for 6 weeks followed by massage energetic passive motion X ray therapy and diathermy for 8 months



2758 June 2 1937 2759

Fig 2758 2759—Same case 2 years following arthrodesis Ankle joint fused Bony union between tibia and talus Walking painless and enduring

116 ARTHRODESES OF THE TALOCRURAL, SUBTALAR AND TALONAVICULAR JOINTS

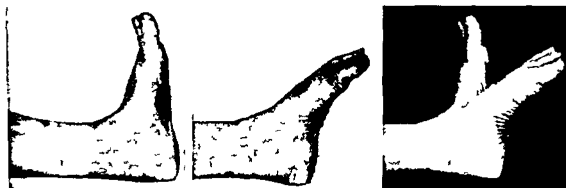
Indications for Arthrodesis Since it is seldom possible to achieve satisfactory reduction in old posterior and anterior fracture dislocations and comminuted impaction fractures and since painful arthrosis due to cartilage

damage often arises following apparently successful late reductions, it is expedient to carry out arthrodesis early as in figures 2770, 2771 In medial and lateral fracture dislocations it is sometimes possible to effect reduction conservatively as late as 10 weeks after the injury and operatively after many months at figures 2747—2753 a show



2760 September 30 1935 2761

FIG 2760 2761 —Bony ankylosis of the ankle joint in a 56 year old man who sustained an open injury of the ankle joint which led to infection and ankylosis Gait painless without a limp The roentgenograms show that the movements take place in the talocrural and talonavicular joints



2762 2763 2764

FIGS 2762—2764 —Photographs accompanying figs 2760 2761 Range of motion of 30°

Arthrodesis should also be considered when the cartilage has been badly damaged by inadequate immobilization, early massage and energetic passive movements (figs 2756—2759)

Extirpation of a large joint is a major intervention and therefore may be carried out in spontaneous arthrosis and inflammatory diseases only if symptoms of long duration are present, walking is sharply limited, if every demand on the joint produces severe pain and if all other treatment carried out over months or years has failed Before operation the type and duration of treatment namely hospitalization for 3 to 4 weeks and immobilization in walking cast for 3 to 4 months and the necessary time required to achieve a painless and useful extremity are discussed with the patient Five to twelve months are required to achieve complete freedom from pain in arthrodesis of the

5 Have I carried out fixation with screws with the ankle in the dorsiflexed position?
6 Have I inserted the screws from dorsal laterally to ventral medially?
7 Have I filled the tibiofibular joint space with bone chips after the screw fixation?
8 Have I immobilized the ankle joint in a short leg walking cast for 12 weeks following the operation?



2756 [illegible] 2757

Fig. 2756, 2757.—2 year old fracture of [illegible] malleolus. Talus in normal position. Lateral malleolus dislocated 3 mm laterally. Joint space between talus and lateral malleolus is thus widened while that between talus and tibia is narrowed and irregular in its lateral portion. [illegible] 15°. Swelling of the ankle joint. Continuous severe pain on walking and standing. Treated elsewhere by plaster cast for 6 weeks followed by massage, exercises, [illegible]. [illegible] and [illegible] for 8 months.



2758 [illegible] 2759

Fig. 2758, 2759.—Same case 2 years following arthrodesis. Ankle joint fused. Bony union between tibia and talus. Walking painless and [illegible].

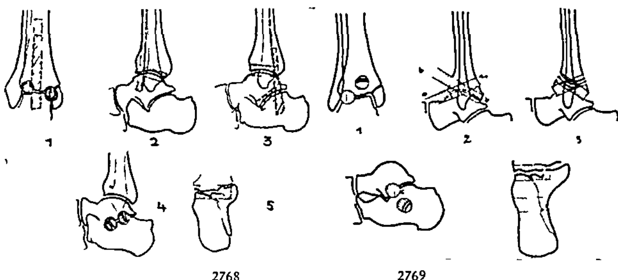
116. ARTHRODESES OF THE TALOCRURAL, SUBTALAR AND TALONAVICULAR JOINTS

Indications for Arthrodesis. Since it is seldom possible to achieve [illegible] reduction in old posterior and anterior fractures of [illegible] and comminuted impaction fractures, and since painful arthrosis due to cartilage

We have occasionally used the dowel arthrodesis according to Lange for the talocalcaneal joint

Removal of cartilage and freshening of all joint surfaces with screw fixation or compression are procedures of considerable magnitude and require considerable time Therefore in recent years we have used the sliding graft from the anterior or posterior surface of the tibia for the ankle joint and as the simplest procedure the rotation bolt arthrodesis for the talocrural, talocalcaneal and talonavicular joints

Scherbichler's Instrument for Rotation Bolt Arthrodesis The instrument consists of a steel rod with a flat projecting blade (fig 2765) and a cylindrical



Figs 2768 2769 — Various types of arthrodeses of the talocrural and talocalcaneal joints

Fig 2768/1 2 — Arthrodesis of the ankle joint with a sliding graft from the tibia and two rotation bolts seen from in front and from the side

Fig 2768/3 — Arthrodesis of the talocrural and talocalcaneal joints with a posterior sliding bone graft from the tibia and freshening of the joint surface of the talocalcaneal joint which is filled with bone chips Presented only from the side

Fig 2768/4 5 — Arthrodesis of the talocalcaneal joint with two rotation bolts taken out of the joint

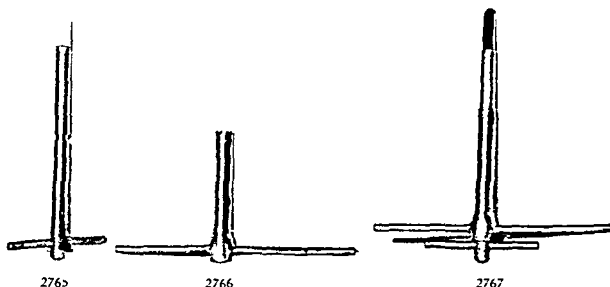
Fig 2769/1—3 — Arthrodesis of the ankle joint with two rotation bolts that cross at the mid portion of the joint 1 seen from in front 2 and 3 from the side

Fig 2769 below — Arthrodesis of the talocalcaneal joint with a solid rod removed from the body of the calcaneus which is exchanged for the two half cylinders from the joint

saw 14 mm in diameter which slides over it (figs 2766, 2767) These instruments are also available in diameters of 20 and 25 mm The largest is used for the hip joint The blade is inserted into the joint and a bone bolt is bored out with the cylindrical saw This bolt consists of the joint surfaces and adjoining bone of the two sides of the joint Then the steel rod and thus also this bolt is rotated through 90° Thus the joint is stabilized and ankylosis will gradually develop

Arthrodesis of the Talocrural Joint The operation is carried out in a bloodless field maintained by tourniquet under general anesthesia If significant

subtalar joint while one to two years are required for the talonavicular and talocrural joints It may require two to four years if all three joints are fused There is usually no pain while the patient is in the cast and after removal of the cast the symptoms are not as severe as before operation They continue to subside and usually disappear completely in the periods given above When we have explained this to the patient we wait until the patient himself requests the operation usually after he has used many forms of treatment without improvement



Figs 2765—2767 Steel rod with blade and groove and cylindrical saw according to Scherbichler for rotation bolt arthrodesis.

Fig 2765 – Steel rod with blade

Fig 2766 – Cylindrical saw 14 mm in diameter

Fig 2767 – The steel rod with blade is inserted into the cylindrical saw When the cylindrical saw reaches the groove its distal end has reached the end of the projecting blade

Figs 2765—2769 has been taken from a paper by Scherbichler[1]

Contraindication Impaired circulation with absence of the pulses on the injured foot and palpable pulses on the other foot is a contraindication to operation If the general condition is satisfactory age is of little importance In general we carry out the operation up to the age of 60

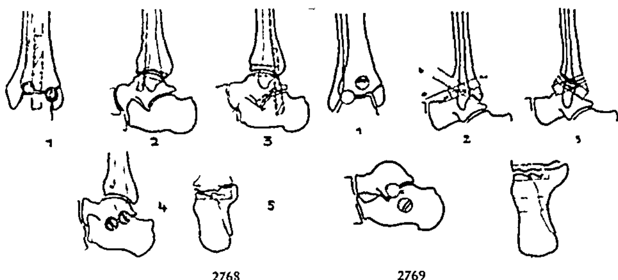
Techniques of Operation Over the years we have used many methods of arthrodesis for *various joints These methods embodied excision of the* cartilage alone and fixation of the bones with wire or screw fixation In arthrodesis of the ankle joint we divided the malleoli and removed the cartilage of the joint with a curved chisel so that the two bone surfaces fit accurately on one another We have utilized the compression arthrodesis according to Greifensteiner It is however not as satisfactory here as at the knee joint After this we used sliding grafts from the anterior or posterior tibial surface (figs 2765/1, 2, 3 and 2770—2773) and rotation bolt arthrodesis (figs 2768/4, 5 and 2769)

1 Scherbichler R 1955 ‚Arthrodese des Fußes Wien med Wschr 105 342—345

We have occasionally used the dowel arthrodesis according to Lange for the talocalcaneal joint

Removal of cartilage and freshening of all joint surfaces with screw fixation or compression are procedures of considerable magnitude and require considerable time Therefore in recent years we have used the sliding graft from the anterior or posterior surface of the tibia for the ankle joint and as the simplest procedure the rotation bolt arthrodesis for the talocrural, talocalcaneal and talonavicular joints

Scherbichler's Instrument for Rotation Bolt Arthrodesis The instrument consists of a steel rod with a flat projecting blade (fig 2765) and a cylindrical



Figs 2768 2769 – Various types of arthrodeses of the talocrural and talocalcaneal joints

Fig 2768 1 2 Arthrodesis of the ankle joint with a sliding graft from the tibia and two rotation bolts seen from in front and from the side

Fig 2768/3 – Arthrodesis of the talocrural and talocalcaneal joints with a posterior sliding bone graft from the tibia and freshening of the joint surface of the talocalcaneal joint which is filled with bone chips Presented only from the side

Fig 2768/4 5 Arthrodesis of the talocalcaneal joint with two rotation bolts taken out of the joint

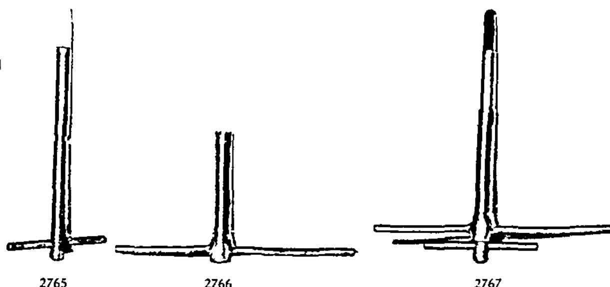
Fig 2769/1—3 Arthrodesis of the ankle joint with two rotation bolts that cross at the mid portion of the joint 1 seen from in front 2 and 3 from the side

Fig 2769 below –Arthrodesis of the talocalcaneal joint with a solid rod removed from the body of the calcaneus which is exchanged for the two half cylinders from the joint

saw 14 mm in diameter which slides over it (figs 2766 2767) These instruments are also available in diameters of 20 and 25 mm The largest is used for the hip joint The blade is inserted into the joint and a bone bolt is bored out with the cylindrical saw This bolt consists of the joint surfaces and adjoining bone of the two sides of the joint Then the steel rod and thus also this bolt is rotated through 90° Thus the joint is stabilized and ankylosis will gradually develop

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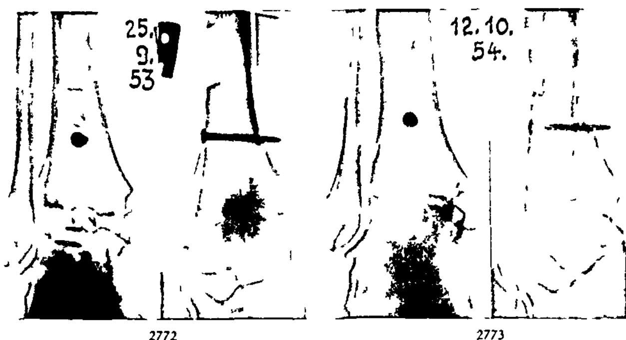
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1 Scherbichler R 1955 Arthrodese des Fußes Wien med Wschr 105 342—345

Fixation of the Large Bone Graft and Insertion of Bone Chips into the Joint When the X rays show the bone graft to be in a good position it is fixed at the upper end with a screw which should not be too long (figs 2771 to 2773) The gaps in the ankle joint resulting from the removal of the cartilage are firmly packed with bone chips from the head of the tibia, from the crest of the ilium or from a bone bank



2772 2773

Fig 2772—Fresh arthrodesis after a 10 month old fracture of both malleoli which had healed with marked narrowing of the joint space of the ankle Sustained by a 38 year old roofer who fell 5 M from a scaffold The operation was carried out because he had continuous pain during walking and was unable to work The ankle joint was exposed Then a rotation bolt arthrodesis was carried out with one rotation bolt in the ankle joint and another in the medial joint space Both bolts were rotated 45° Then an 8 cm long 1 cm wide sliding graft was cut out from the tibia wedged into the neck of the talus and fastened with one screw The screw is too long After operation temporary cast for 2 weeks followed by a short leg walking cast for 12 weeks

Fig 2773—Same case after a year The ankle joint has fused by bony union anteriorly and by scar tissue posteriorly At reexamination after two years walking was painless and enduring

Rotation Bolt Arthrodesis of the Ankle Joint We currently prefer multiple rotation bolt arthrodesis with the Scherbichler instrument (figs 2769/1—3) to the technically more difficult removal of the cartilage The blade of the instrument is carefully introduced into joint in order not to spread the bones apart (figs 2772 1773) When it reaches the apex of the talus it enters the posterior part of the tibia At this point a lateral roentgenogram is made to determine the position of the instrument, namely it is introduced far enough but not too far When the position is shown satisfactorily a bone peg is cut with the cylinder saw The peg consists of two half cylinders anteriorly and a full cylinder posteriorly The bone bolt can then be rotated 90° or can be removed and reversed and tapped back into its bed Then the blade of the instrument is driven into the tibia from a point 15 mm above the joint

angulation is present it must be first corrected by osteotomy Otherwise an anterior longitudinal incision is made over the ankle joint The cartilage is removed from the talus and the tibia including both malleoli and an 8 to 10 cm long and 1 cm wide bone is chiseled from the tibia and a hole is made into the neck of the talus 1½ cm deep and ½ cm in anteroposterior diameter The graft from the tibia is slid into this hole with the ankle at 100° to 110° and is impacted



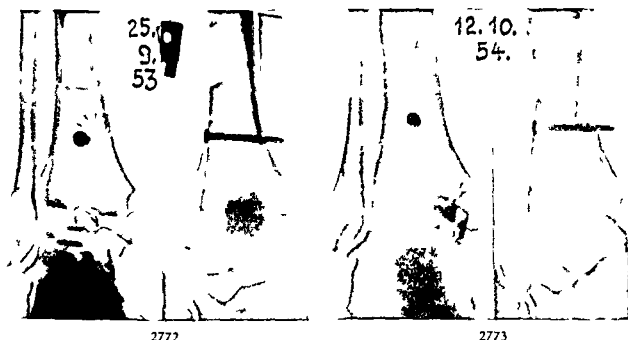
2770 September 9 49 2771 October 9 50

Fig 2770 – 10 week old supination external rotation fracture stage 4 Incurred by a 63 year old woman when she slipped and fell on a meadow Torsion fracture of the lateral malleolus at the level of the joint and shearing off of a narrow dorsal wedge Dislocation of the talus with the dorsal wedge by half its width posteriorly and proximally Treated *elsewhere* by *plaster immobilization for 7 weeks* without previous reduction *Presented herself to us after* 10 weeks because of pain on walking and marked swelling of the foot *Treatment* Under general anesthesia with the use of a tourniquet the ankle joint was exposed by an anterior longitudinal incision The scar tissue was removed from the anterior portion of the ankle joint The cartilage was removed from the joint surface of the talus including the surfaces that articulate with the malleoli and from the lower joint surface of the tibia and the malleoli A transverse hole 10 mm wide 15 mm deep and 5 mm in sagittal diameter was chiseled out of the neck of the talus A 10 cm long 1 cm wide bone graft was taken from the anterior surface of the tibia After the foot was replaced anteriorly the tibia graft was wedged into the hole in the neck of the talus with the foot in 110° plantar flexion In order to avoid later displacement the graft is fixed to the tibia with a screw The spaces between the tibia the malleoli and the talus that have resulted from the removal of the cartilage are tightly packed with bone chips Temporary cast split for 2 weeks followed by a short leg walking cast for an additional 10 weeks

Fig 2771 —Same case after 13 months Solid well united ankylosis between tibia talus and lateral malleolus in good position in both planes The screw is much too long Toes move through only ⅓ their normal range talocalcaneal and talonavicular joints only minimally movable Ankle joint immobile at 100° Pain only on prolonged walking Able to walk at home without a cane

Roentgen Check Roentgenograms are taken in this position in both planes to determine the depth of penetration of the bone graft and the position of the ankle

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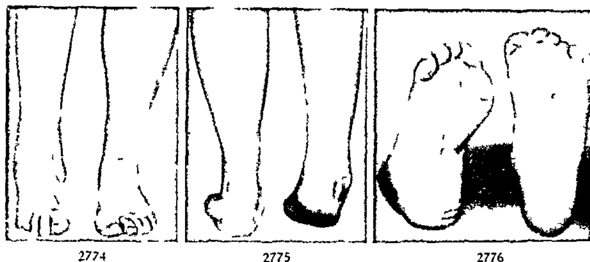
2772 2773

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space at an angle of 60° to 65° to the shaft of the tibia in order to penetrate the posterior part of the joint space (figs 2769/1—3) Here it is particularly important to verify the position of the blade in the posterior joint space with a



2774 2775 2776

Fig 2774 Traumatic club foot with heel cord shortening Incurred by a 32 year old woman after a closed fracture of both malleoli treated *elsewhere* with bone clamp and traction The clamp was placed into the talocalcaneal joint After 3 weeks infection of the joint developed Thereupon the clamp was removed Further treatment without immobilizing bandage Bony union of the talocrural talocalcaneal and talonavicular joints Condition 1 year after injury



2777 2778 April 17 1938 2779

Figs 2777—2779 —Comparison photographs to figs 2774—2776 after removal of a piece of bone from the head of the talus and the calcaneus The shape of the foot is again normal Foot shortened

lateral roentgenogram If the position is unsatisfactory, the instrument must be pulled out and driven in again The lateral roentgenogram must then be repeated As soon as the blade is in satisfactory position the bone peg is cut with the cylinder saw pulled out, reversed re-introduced (figs 2769/1—3) and driven home with an impactor The procedure is carried out in the same manner between the malleoli and the talus This type of arthrodesis seems

to me to be the simplest and least traumatic since it is not necessary to widely expose the bones and circulation is not significantly disturbed

In order to avoid marked swelling which interferes with the blood supply hydrocortone is usually injected after wound closure

After every arthrodesis a temporary short leg bed cast is applied for 2 to 3 weeks followed by a short leg walking cast as described on pages 1920 to 1932 for an additional 12 to 14 weeks

Results after arthrodesis of the ankle joint are usually very good after 1 to 2 years In young individuals mobility in the talonavicular and talocalcaneal joint increases to such a degree that the ankylosis is not noticeable (figs 2760—2764) A woman in whom I fused the ankle joint because of a malunited malleolar fracture when she was 25 demonstrates the function



2780 January 2 1936

Splint for correction of heel cord shortening After application of the usual Unna paste dressing a 20 cm wide muslin strip is included in the dressing on the posterior side of the lower leg and is placed around the foot and the opposite shoulder as shown and tied in such a way that through extension of the knee a dorsiflecting force is exerted A small board is inserted at the sole of the foot to protect the toes and to increase the dorsiflecting force through leverage Method of Kromer [1]

that can be achieved Although in the first year she was dissatisfied with the result, she is now not only free from pain but is so active that she sends me a card every summer from a different mountain peak of over 3000 M that she had climbed

ROTATION BOLT ARTHRODESIS OF THE TALOCALCANEAL JOINT

The talocalcaneal joint is exposed through a curved incision under the lateral malleolus The peroneus tendons are retracted distally Then the blade of the Scherbichler instrument is driven into the posterior portion of the talocalcaneal joint to the proper depth A roentgenogram is taken from the sole to the dorsum of the foot to verify its position Then a bone peg is cut out of the talus and the calcaneus in the manner described for the ankle and is turned 90° Instead of this a solid peg can be removed from the body of the calcaneus and interchanged with the two half cylinders from the talus and the calcaneus (fig 2769 below) Further treatment follows as for arthrodesis of the ankle joint

[1] Kromer 1936 *Eine einfache Quengelmethode gegen Spitzfußstellungen* Der Chirurg *8* 892—894

Instead of the rotation bolt arthrodesis a dowel arthrodesis can be made from the tuber calcanei into the talus as suggested by Lange

Ehalt uses a three flanged nail as used for hip-nailing for immobilization after arthrodesis of the talocalcaneal joint instead of a cast He carries out arthrodesis by removal of cartilage and insertion of bone chips This nail is driven over a guide wire from the neck of the talus through the posterior talocalcaneal joint into the tuber calcanei

Arthrodesis of the Talonavicular Joint

Rotation bolt arthrodesis can be used also for this joint The joint is exposed through a lateral curved incision between the calcaneus and cuboid

Treatment of Traumatic Club Foot

If infection follows a malleolar fracture the foot must be continuously immobilized in good position until the inflammation subsides and ankylosis results If the foot is not immobilized in a cast a traumatic pes equinovarus can result as shown in figures 2774—2779

To correct this deformity a curved incision is made beginning behind the lateral malleolus and extending to the fifth metatarsal A proper-sized wedge is removed from the lateral side of Chopart s joint This allows the foot to be abducted and pronated The supination of the heel is corrected by *removal of a horizontal wedge of bone from the calcaneus When the foot* appears outwardly normal, the bones are stabilized by insertion of crossed wires Further treatment is carried out in a temporary short leg bed cast for 2 to 3 weeks followed by a short leg walking cast for an additional 12 to 14 weeks

Treatment of Traumatic Pes Equinus

If pes equinus follows an injury, it can in the first few months be corrected by exercise carried out as shown in figure 2780 If it has been present for more than six months, an oblique percutaneous tenotomy of the Achilles tendon is carried out, and a cast is applied after correction of the pes equinus for four weeks

Ankylosis of the joint in plantarflexion is then possibly corrected by a *V-osteotomy through an anterior incision avoiding the previously infected* bone Then a temporary long leg bed cast is applied for 2 to 3 weeks followed by a short leg walking cast for 7 to 8 weeks This is followed by an Unna s paste dressing

MALLEOLAR FRACTURES IN THE PRESENCE OF ADVANCED SYPHILIS AND TABES

Diagnosis of Tabes If the knee reflexes and pupillary reflexes are routinely tested in every patient (see p 1906), tabes as a rule will not be overlooked The diagnosis can often be made at first glance from the small unreactive or irregular pupils If striking insensibility to pain is found even in

the presence of pupillary reflexes, tabes should be considered and a previous history and syphilis should be sought Cloudy callus formation following fractures and arthropathies are signs of tertiary syphilis and often the first signs of tabes They may precede reflex changes by months or years We are therefore often able to make the diagnosis of tabes from the roentgenogram long before the neurologist can find any abnormal signs

Treatment Reduction is carried out in the manner described on pages 1919 and 1920

Immobilization is carried out in the manner described on page 1920

Consolidation in tabes usually takes twice as long as in individuals without tabes

Duration of Immobilization In individuals without tabes plaster immobilization may be discontinued when the fracture is clinically sound even when the fracture line is clearly visible They will initially use their leg cautiously and avoid activity which causes pain In tabetics on the other hand pain sensibility is largely or completely absent Because of the absence of pain and because of the ataxia he uses his leg ruthlessly The bone bends because it is soft and union is not yet complete In order to avoid this immobilization in cast or traction must be continued at least twice as long as normally, namely until the fracture is completely healed on X-ray Old syphilis is treated by antibiotics In tabes the value of antibiotics is questionable

Case 1 A 53 year old patient (figs 2781—2784) sustained a fracture of the tip of the lateral malleolus after a fall of one story He arrived at the hospital on foot five hours after the accident in spite of unusually severe swelling over the lateral malleolus He was treated for five days with compresses followed by a short leg walking cast which was inadvertently removed after 5 weeks rather than after 12 to 15 weeks When after 13 weeks the first signs of arthropathia tabica were discovered patient was supplied with a brace Inspite of the brace the deformation of the joint progressed so rapidly that two years later an amputation had to be performed

In those individuals in whom we continued immobilization in a short leg walking cast at least twice as long as in non-tabetics, arthropathies as a rule did not appear as the following example shows

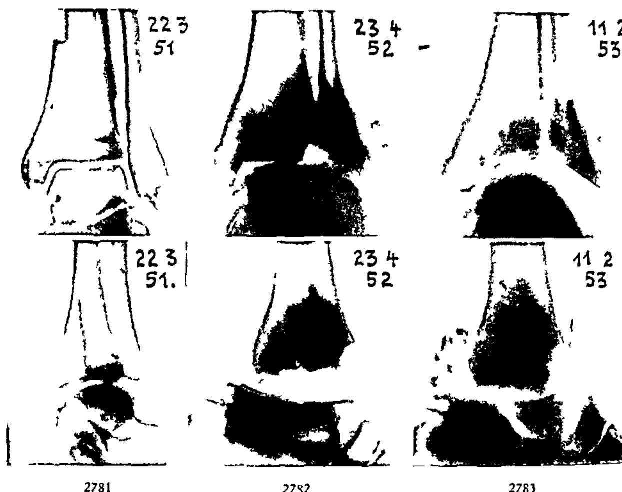
Case 2 A 49 year old tabetic sustained a torsion fracture of the lateral malleolus with lateral subluxation of 3 mm a much more serious fracture than in case 1 The fracture was immediately reduced and immobilized in a temporary cast for one week and a lower leg walking cast for an additional 19 weeks Follow up examination after three years showed the joint to be normal

Operative Treatment of Fractures in Tabetics These fractures should be treated very conservatively because the later appearance of arthropathies in patients who were able to work before their accident are not uncommonly attributed to the surgeon I myself have been involved in an unpleasant legal action concerning a fracture of a femur in a tabetic (see Vol II/p 1441) I know of two similar cases in malleolar fractures Trojan[1] has published several of our experiences with fractures in tabetics

Treatment with Braces in Tabetic Arthropathy following Malleolar Fractures In fresh malleolar fractures of tabetics the short leg walking cast must remain twice as long as in a non tabetic patient Following this braces are not necessary However if joint changes appear because of immobilization of too

[1] Trojan E Erfahrungen mit Frakturen der unteren Extremitaten bei Tabikern 47 Heft zur Unfallheilkunde 208—211 1953

short duration a brace must be applied in order to avoid angulation and to maintain him in condition to walk and to work In the patient pictured in figures 2785—2786 this was achieved to a great degree The changes have



2781 2782 2783

Fig 2781—2783 –Rapid development of tabetic arthropathy over a period of 2 years after fracture of the tip of the lateral malleolus Sustained by a 52 year old laborer in a fall from a scaffold from a one story height

Fig 2781 –Fine fissure through the tip of the lateral malleolus

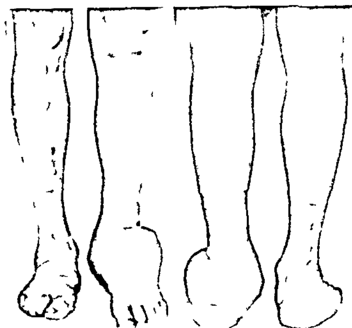
Fig 2782 –Same case after 13 months The lateral side of the joint surface of the tibia is destroyed The tip of the lateral malleolus is absent On its lateral side a large bone shadow is visible In the lateral film the trochlea of the talus has disappeared The cranial portion of the talus is concave The joint space is very wide

Fig 2783 –Same case after 23 months The trochlea of the talus no longer appears as a trapezoid from in front but rather as a triangle There is further destruction of the lower surface of the tibia and the lateral malleolus In the lateral film a frontal fracture line extends through the middle of the talus The posterior portion of the talus is largely reabsorbed Bone shadows can be seen radiating from around the joint The joint space is again narrower

gradually increased in the course of nine years but he has adequately maintained his ability to work with the help of a brace

In the patient in figures 2781—2784 a the condition progressed rapidly in spite of the brace and caused such severe pain and disturbance of walking that a below the knee amputation was necessary

Acknowledgment of a Tabetic Arthropathy as an Industrial Accident Since most tabetic arthropathies develop without any particular relation to occupation, the industrial accident insurance carrier usually does not allow

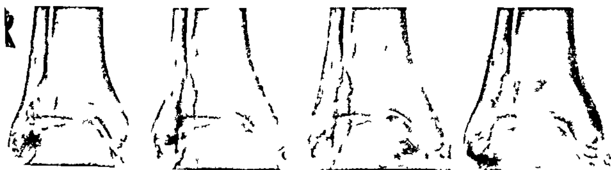




2784 January 28 1953 2784 a

Fig 2784 — Photograph corresponding to fig 2783 Unusually marked thickening of the ankle joint especially in the region of the lateral malleolus

Fig 2784 a — Sagittal section through the ankle joint of the amputated foot Only a small portion of the body of the talus remains visible The remainder of the body of the talus darkly impregnated with blood The lower surface of the tibia is ground flat



2785 June 17 1946 2786 December 13 1950 2787 February 16 1953 2788 February 14 1955

Figs 2785—2788 — Gradual development of tabetic arthropathy over a period of 9 years

Fig 2785 — 2 years after injury of the ankle Destruction visible at the medial angle of the tibia

Fig 2786 — Same case after 4½ years The destruction at the medial angle of the joint has increased Therefore the medial malleolus appears longer Its tip is broken off

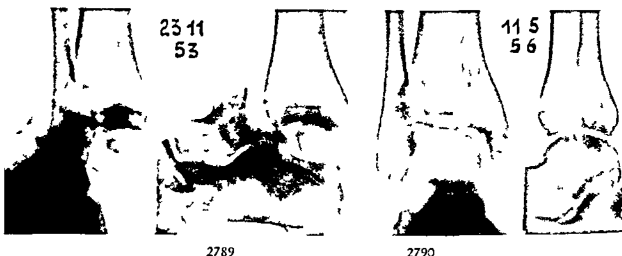
Fig 2787 — Same case after 7 years The destruction at the medial angle of the joint has further increased The medial malleolus therefore appears still longer

Fig 2788 — Same case after 9 years The joint space is narrower and the medial malleolus appears to have grown still longer The tip which had been broken off has reunited

claims for compensation in these cases When however an incident occurred that was certainly related to occupation as in the patient of figures 2781 to 2784, who fell one story and immediately thereafter developed severe swelling from a fresh hematoma at the lateral malleolus and showed a crack in the lateral malleolus on X-ray in an otherwise normal ankle, the subsequent arthropathy must be considered as resulting from an industrial accident

Questions We Should Ask Ourselves to Avoid Failures in the Treatment of Malleolar Fractures in Tabetics

1 Have I examined the pupillary reflexes and tested the knee jerks in every patient with a fracture, a dislocation or other joint injury?



2789 2790

Fig 2789—Complete anterior dislocation of the right foot with shearing off of the medial malleolus 1 mm impression of the anterior lower edge of the tibia The talus is displaced laterally by two thirds its width The posterior surface of the calcaneus is in line with the posterior edge of the fibula In addition a contused open wound at the lateral side of the knee joint extending into the joint Sustained by a 22 year old mason who collided with an automobile while riding a motorcycle *Treatment* Reduction of the foot under local anesthesia with the hip and the knee sharply flexed Wound excision at the knee and ankle and application of hip spica cast because of the open wound of the knee joint

Fig 2790—Same case after 2½ years Normal form of the ankle joint The medial malleolus has healed in good position The anterior edge of the joint surface of the tibia shows slight lipping Active mobility of the toes normal talocalcaneal joint mobile through half its range Ankle joint has a range from 80° to 115° as compared to 75° to 120° on the left Gait without limp No complaints

2 Have I immobilized the fracture or joint injury in a tabetic at least twice as long as under normal circumstances?

3 Have I on appearance of cloudy callus formation recognized this as a sign of tertiary syphilis and continued immobilization twice as long as otherwise?

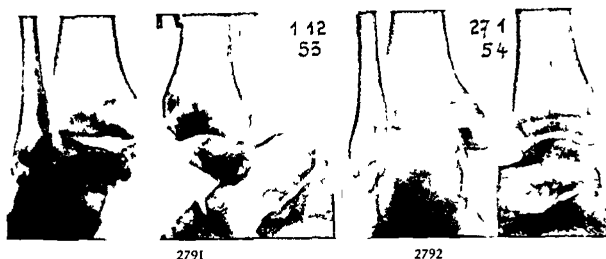
4 Have I as a rule avoided surgery in tabetics?

5 Have I as a rule prescribed a brace for tabetic arthropathy?

6 In a tabetic arthropathy that was certainly related to occupational accident, have I acknowledged this as an industrial accident?

117 DISLOCATIONS AND JOINT RUPTURES OF THE ANKLE JOINT

Mechanism Dislocations in the ankle joint can only occur anteriorly or posteriorly because the malleoli prevent lateral dislocation One should speak of dislocation only when all three positive signs are present (Vol I/p 51), namely, deformity, springy fixation and empty socket The body of the talus must be displaced anteriorly or posteriorly by its full width Special emphasis should be placed on springy fixation which is absent in the usual fracture dislocations (figs 2703, 2704, 2731—2736) and in the rare joint ruptures Ehalt[1] has described a case Pure dislocation of the foot with the talus in the presence of a completely intact ankle mortise as seen in the roentgenograms of Ehalt occur only with open joint ruptures



2791 2792

Fig 2791 —Closed complete posterior dislocation of the right foot Sustained by a 27 year old fireman when a rope holding the basket in which be was riding broke and he fell 22 M The talus is dislocated posteriorly by the full width of its trochlea The medial malleolus is avulsed The posterior process of the talus is broken off and the lower posterior edge of the tibia is impressed Valgus position of the talus of 20° Simultaneous supra and diacondylar fracture of the right femur and diacondylar fracture of the head of the right tibia as well as an open fracture of the shaft of the left femur

Fig 2792 —Same case after 8 weeks Normal form of the ankle The medial malleolus has healed in good position Follow up examination after 2 years Mobility of toes normal Movement of talocalcaneal joint limited by one third mobility of ankle 75° to 125° on the left No complaints referable to the ankle

True posterior dislocation of the foot results from rapid maximal plantar flexion associated with mild longitudinal traction and not from axial impaction as in the posterior shearing fracture shown in figure 2521 The capsule tears anteriorly and the talus slips over the posterior edge of the lower tibial joint surface This is impressed by 1—2 mm The posterior process of the talus is sheared off The medial malleolus which is attached to the talus and the navicular bones by the deltoid ligament is avulsed (fig 2791) Therefore the fore foot appears to be shortened and the heel projects sharply The foot is

[1] Ehalt W Luxatio pedis cum talo Wien Klin Med 2 725—729 1947

fixed in this position with a springy fixation Longitudinal furrows are produced on both sides On the dorsum of the foot the skin is pulled inwards producing a transverse trough below a slight bulge produced by the lower end of the tibia The tendons of the flexors of the toes, especially that to the great toe now traverse a greater distance and the great toe is therefore fixed in maximal *plantar flexion as in figure 2827* The arteries on the anterior and posterior sides of the ankle joints are so stretched that blood flow is impeded, and the foot is cold white and pulseless It is also anesthetic because of the stretching of the nerves

True anterior dislocation of the foot results from maximal dorsiflexion and traction and not from axial impaction as does the anterior shearing fracture in figure 2522 It cannot be produced experimentally in the cadaver because the corresponding momentum and therefore the traction is not reproduced Due to the violence the anterior edge of the tibial joint surface is avulsed anteriorly This is somewhat impressed The medial malleolus has already been broken off due to maximal dorsiflexion by the head of the talus which is wider anteriorly than posteriorly (fig 2789) The forefoot appears lengthened and the heel no longer projects normally The posterior surface of the leg now is convex rather than concave as in the normal The foot is fixed in this position with springy fixation The lateral malleolus projects down further than on the sound side Because of the anterior displacement *the flexors of the toes traverse a greater distance The great toe is therefore* fixed in flexion as in figure 2827 The vessels are also stretched so that circulation is impeded The foot is therefore white or livid and pulseless Because of the forceful stretching of the nerves it is also anesthetic

Diagnosis These dislocations can easily be recognized by springy fixation of the ankle associated with abnormal shape of the foot and ankle There is lengthening of the forefoot in anterior dislocation and shortening of the forefoot in posterior dislocation Especially striking is the white or the livid color of the foot which is cold and pulseless and the plantarflexion of the great toe as in figure 2827 In addition anesthesia is present due to the overstretching of the nerves and the ischemia In the usual fracture dislocations the color of the foot is normal and the pulse is palpable There is no springy fixation

Treatment Because of the blood vessel and nerve damage the foot must be reduced as early as possible We use local anesthesia In order to relax the Achilles tendon the knee is bent to a right angle and the foot plantar flexed *(see Vol I/figs 1—6) If this is inadequate the knee can be fully flexed as* well as the hip Then the heel is grasped with one hand and the forefoot with the other and the foot is pulled downwards as in taking off a shoe In posterior dislocations the foot is pulled forwards and in anterior dislocations it is pushed backwards Reduction usually follows in a few seconds with an audible sound, and the medial malleolus resumes its normal position If reduction can be carried out in the first few hours after the injury *the foot at once* regains its normal color, and the pulse again becomes palpable Sensation returns, and toes and ankle can be actively moved

I once saw an 18 year old boy five months after injury in whom the foot had not been reduced The toes and outer margin of the foot were gangrenous

Roentgen Check After reduction roentgenograms must be obtained in both planes with the leg rotated 20° inwards

Immobilization When the roentgenograms show good position a temporary bed cast is applied for a week followed by a short leg walking cast for an additional nine weeks In open dislocations the temporary cast must remain until the wound is healed

Results If reduction has been carried out early the results are good Mobility becomes nearly normal

Simon-Weidner[1] has described two of our cases in detail

PARTIAL DISLOCATION OF THE TALUS IN SUPINATION

Frequency Partial dislocation of the talus in supination (figs 2678 to 2682) belongs to the most common injuries, while supination-adduction fractures are comparatively uncommon We treat about 600 sprains of the ankle a year Of these about 54 to 58 are supination subluxations They occur most commonly between the ages of 25 and 35, while supination-adduction fractures occur more commonly in patients over 40

Mechanism Partial dislocation of the talus in supination results when the body turns outward on the foot while the latter is fixed Adduction and inward rotation of the forefoot and supination of the entire foot results The weight of the body then falls on the outer border of the foot and is born by the ligaments and the peronei If the strain is too great, severe sprain or tear of the ligaments and capsule on the outer side of the ankle joint results In heavy persons this injury can occur from turning one's ankle on level ground, in others from slipping off a curb or a step or in sport, i e, football, skating and especially in skiing Supination-adduction fracture dislocations as a rule require a fall on the outer margin of the foot from a height of at least 0 5 M for their production

Anatomic Changes My former assistant Guttner has reproduced the injury in 52 cadavers In half, the ligaments were dissected out first, while in the remainder dissection was not carried out until after the injury He found the following First a partial and then a complete tear of the anterior ligament (ligamentum talofibulare anterius) occurs The joint is then loosened only slightly As a result of further supination of the foot the posterior ligament (ligamentum talofibulare posterius) began to split up in the direction of its fibers up to the point of crossing of the calcaneofibular ligament If adduction and inward rotation is now carried out with considerable force this lower ligament also tears to the lateral process of the talus The joint can now be opened to 50°

[1] Simon Weidner R Zur Totalluxation des Fußes im oberen Sprunggelenk (Luxatio pedis cum talo) Arch Orthop u Unfall Chir *47* 56—64 1955

Guttner 1941 Erkennung und Behandlung des Banderrisses am außeren Knochel mit Teilverrenkung des Sprungbeines im Sinne der Supination (Subluxatio supinatoria pedis) Arch Orthop u Unfall Chir *41* 287—298

The anterior ligament usually tore across its middle, the posterior was split longitudinally and the lower tore at its upper insertion at the tip of the malleolus or at the posterior outer surface of the body of the calcaneus A small flake of the lateral malleolus (figs 2680—2682) or of the calcaneus was often avulsed, especially in older individuals In those over 50 the lateral malleolus often tore out 1 to 1 5 cm above its tip

Diagnosis At the time of injury the patient hears a crack and develops a severe pain at the lateral malleolus The ankle joint is swollen on its outer side and after several hours is discolored, especially below and anterior to the lateral malleolus and especially at the outer border of the foot On the second day the discoloration is found mainly along the outer border of the foot occasionally down to the toes The discoloration is not present along the lateral part of the sole of the foot The joint is very tender in front of, below and behind the tip of the lateral malleolus If the point of maximal tenderness is located between the lateral malleolus and the calcaneus partial dislocation is very likely The only certain clinical sign is the impact of the talus on the joint surface of the tibia during attempts to pronate and supinate In fresh injuries this is seldom demonstrable because of the reflex muscle spasm but is easily demonstrated in old injuries

Local Anesthesia As soon as one injects 20 cc of 2% Novocain in front of and below the lateral malleolus the pain and therefore the reflex muscle spasm disappears, and the joint surfaces can be easily separated

Roentgen Examination The type of injury and its true extent can only be determined with special roentgen technique under local anesthesia First the usual roentgenograms of the ankle are made in both planes as in figures 2627—2632 On these an avulsion of the tip of the lateral malleolus can be seen (fig 2680) This usually suggests a severe injury Then anteroposterior stress roentgenograms are made of both ankles in order that they can be compared with one another For these the foot with the patella pointing forward is rotated inward and supinated as far as possible (fig 2686) The extent of the ligamentous tear can be estimated from the distance in millimeters between the outer upper edge of the talus to the lateral end of the tibia This can also be expressed in terms of the angle in degrees between the upper surface of the talus and the lower joint surface of the tibia rather than distance in millimeters When the tip of the malleolus is avulsed, the fragment is seen to be separated from the fibula on spreading the joint (fig 2681) The greatest spreading of the joint observed by us was 70° (fig 2686 e)

Treatment of Partial Dislocation of the Talus in Supination

Reduction is not necessary because the displacement disappears when the dislocating stress is removed

Immobilization A temporary lower leg bed cast is applied for 4—8 days followed by a lower leg walking cast for 5 to 14 weeks as for pronation fractures (figs 2644—2650 and pp 1920—1932), namely in 5° to 10° plantarflexion with slight supination of the heel and slight pronation of the forefoot

Roentgen Check after application of the cast is not necessary because redislocation does not occur if the foot is immobilized in normal position and not adducted and supinated as in figure 2661

Changing of the Cast If the cast becomes loose or breaks before the time of intended removal a new cast is applied During the changing of the cast the joint must not be supinated as this will break the recently formed adhesions and make healing impossible It is particularly important not to take stress films of the joint at this time

Duration of Immobilization If the joint can be opened to 8 to 10 mm, immobilization is carried out for 6 weeks if 10 to 15 mm, for 8 weeks if 15 to 25 mm, for 10 weeks, and over 25 mm for 12 to 14 weeks If the joint is not immobilized or is immobilized for too short a time the joint remains loose and the ankle easily turns even on level ground and the leg tires quickly There is often swelling uncertainty in walking and inability to participate in sports Occasionally the patient is required to change occupation The joint becomes looser with time rather than tighter and can later be opened more widely After several years arthroses develop

Roentgen Check After removal of the cast X rays are obtained in both planes under supination stress

Aftercare After removal of the cast an Unna's paste boot is applied for 2 to 4 weeks Besides that exercises are prescribed as for pronation abduction fractures (see page 1931) Arch supports are as a rule not necessary Most of these patients are able to move the ankle joint through one half of its range of motion immediately on removal of the cast and through its entire range after 14 days

Treatment of Old Partial Dislocations in Supination If the injury is older than 14 days a sound joint can not be achieved even by immobilization of two to 4 months The situation here is the same as that in injuries of the medial collateral ligament of the knee which are older than 14 days In these patients if severe symptoms appear the attempt can be made to replace the anterior and inferior ligament by transplanting the tendon of the peroneus longus muscle

Unsuitable Methods of Treatment

Healing of these ligamentous tears can never be achieved by use of Unna's paste boots, adhesive taping, high shoes arch supports or exercises of the leg muscles

The joint is further loosened by *vigorous massage* and *forceful passive motion*

Injection of novocaine, ethyl chloride or Pancain spray is particularly hazardous because the patients overtax and further damage the ligaments as a result of the absence of pain achieved by the local anesthetic

Results In 1940 Guttner requested our 184 patients of the years 1936 to 1939 to return for reexamination In spite of the war it was possible to reexamine 94 of these 68 replied by questionnaire and 22 were lost at the follow-up

The anterior ligament usually tore across its middle, the posterior was split longitudinally and the lower tore at its upper insertion at the tip of the malleolus or at the posterior outer surface of the body of the calcaneus A small flake of the lateral malleolus (figs 2680—2682) or of the calcaneus was often avulsed, especially in older individuals In those over 50 the lateral malleolus often tore out 1 to 1 5 cm above its tip

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Results In 1940 Guttner requested our 184 patients of the years 1936 to 1939 to return for reexamination In spite of the war it was possible to reexamine 94 of these 68 replied by questionnaire and 22 were lost at the follow up

The 94 that appeared were examined clinically and radiologically with the usual technique plus roentgenograms with the joints under stress

Of the 94 patients the joint could be spread less than 10 mm in 28 and more than 10 mm in 66 before treatment

Of the 28 in whom the joints could be opened less than 10 mm 18 (64%) were clinically and radiologically completely healed and in 10 (36%) the joint could be opened and the symptoms described on page 1997 were present Of the 66 in whom the joint could be opened more than 10 mm 57 (86%) were clinically and radiologically completely healed while in 49 (14%) the joint could be opened and symptoms were present

In all patients in whom the joints could be spread and who therefore had symptoms he found that immobilization had not been carried out long enough, on the average only for three weeks It is striking that the number of bad results is much larger in the less severely injured This can be traced to the fact that some of my assistants had previously underestimated them and therefore failed to immobilize them long enough In those in whom immobilization had been carried out long enough the torn ligaments always reunited, and therefore the joint was stable and yet freely movable

Of the 19 patients in whom the ankle joint could be opened 12 already within 2 to 3 years showed evidence of arthrosis that had not been present at the time of the injury, while in the 75 in whom the joint became stable arthrosis never appeared

The 19 patients in whom the joints could be opened usually had muscle atrophy of the calf of 2 to 3 cm while the remainder without exception showed normal muscular development and freely movable joints in spite of immobilization of 6 to 14 weeks even in old patients

The average duration of disability after removal of the cast was 10 to 14 days in the favorable cases and 4 to 5 weeks in those in whom the joint could be spread

Of the 94 patients 21 drew temporary disability pension for 4 to 6 months

For comparison we wish to cite the results of Dehne[1] who carried out *immobilization for only three to at the most six weeks because of fear of* stiffening of the ankle joint Of 30 patients 24 (80%) had clinically and radiologically bad results and complained of significant pain He erroneously concluded that the severe forms of this injury could not heal

There are still insurance carries who request early massage and passive exercise and often inquire of the physician if this type of treatment is being carried out and how often In fact they often prevent physicians who do not advocate early massage and passive exercise from treating patients insured by them It would be of interest if these patients could be resurveyed and the results published It might then be generally realized that extensive ligamentous tears can heal only during immobilization and never with massage and passive exercise

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1 Dehne Die Klinik der frischen und habituellen Adductionssupinationsdistorsion des Fußes *242* 40—61 1933

SPRAINS AND TEARS OF THE ANKLE

Sprains of the ankle are exceedingly common They always result indirectly through twisting motions that are not forceful enough to lead to fracture of a bone or tear of a ligament If the violence is small only slight stretching of the ligaments results, if it is forceful the ligaments tear or their attachments are avulsed

Mechanism of Production of Sprains or Tears in the Joint between Tibia and Fibula by Inward Rotation of the Body and Outward Rotation of the Foot If the body and the leg suddenly rotate inward on the fixed foot, sprain or tear of the anterior ligament between the tibia and the fibula may result The talus acts as a lever that is rotated outwards in the ankle mortise and disrupts the attachment between the tibia and the fibula Loosening or tearing of the ligamentous juncture between the medial malleolus and the talus and thus loosening of the upper ankle joint occurs simultaneously

Mechanism of Production of Sprains or Tears in the Joint between Tibia and Fibula by Outward Rotation of the Body and Internal Rotation of the Foot If the body and the leg rotate outward on the fixed foot, sprain or tear of the anterior ligament between the tibia and fibula also results The talus then acts as a lever that is rotated inward in the ankle mortise Definite point tenderness can then be found over the anterior surface of the joint between the tibia and fibula

It can occur however that the tibia rotates on its longitudinal axis in relation to the fibula Under these circumstances the anterolateral edge of the joint may be sheared off together with the attachment of the ligament (fig 2619)

Mechanism of Production of Sprains in the Ankle Joint by Supination and internal Rotation of the Foot If the foot suddenly tips over its lateral border and turns inward sprain or tear of the lateral ligaments occur while those on the medial aspect of the joint remain intact This injury is very common (see p 1995)

Sprain of the ankle resulting from external rotation is much less common However, with this mechanism a sprain between the talus and the navicular bone can result and occasionally the tubercle of the navicular bone may be avulsed (fig 2970)

Clinical Examination In all sprains sudden pain occurs that prevents or hinders walking for variable period of time Soon swelling develops associated with more or less hematoma The site of injury is very tender to pressure Most important is examination for abnormal mobility In all ligamentous tears between tibia and fibula the ankle joint is so loosened that the talus can be displaced laterally, and a definite bony knock can be felt at the medial malleolus

If the ligaments of the ankle joint are torn by supination and inward rotation the ankle can initially, before the development of swelling be spread on the lateral side (figs 2679, 2681) and the foot can sometimes be displaced anteriorly After a short time however painful muscle spasm appears that prevents these movements

Local Anesthesia For this reason in all sprains of the ankle the painful sites must be injected with 20 cc of 2% Novocain After anesthesia has been attained it is usually possible to demonstrate the abnormal mobility of the joint

Roentgen Check On the usual roentgenograms an abnormality is present only when attachments of ligaments are avulsed as *in figure 2680 Therefore* in all severe sprains X-rays with the joint under stress must be obtained after local anesthesia It is *not until then that the actual severity of the injury can* be demonstrated (figs 2633—2640, 2679, 2681) It must again be emphasized that small bony avulsions are often unimportant, while ligamentous tears that cannot be demonstrated by the usual X-ray technique but that can only be demonstrated by X-rays taken with the joint under stress after local anesthesia are of greater importance for the later usefulness of the joint

Treatment of Sprains and Tears of the Ankle Joint

Treatment depends on the severity of the injury

In mild sprains application of an Unna's paste boot for 1 to 3 weeks is sufficient

Ligamentous tears can only heal satisfactorily if the dislocation of the joint is accurately reduced under local anesthesia after the swelling is carefully pressed away and a non padded cast is applied at plantarflexion of 5° to 10° at the ankle and immediately split The joint thereupon becomes painless

Duration of Immobilization The cast must remain 4—10 weeks depending on the severity of the injury If it is removed earlier, the torn ligament has not yet healed and the joint remains loose This is particularly likely to *follow subluxations in supination, and such patients turn their ankles repeatedly* and thus sustain new sprains and swellings

Exercises further treatment and roentgen checks are carried out as for the usual malleolar fractures (see pp 1930, 1931) Later on an elastic bandage will be helpful

Unsuitable Treatment Short-wave therapy ultraviolet light and other types of irradiation are superfluous in mild sprains and are of no value in tears but rather are harmful, because the time is lost in which the necessary immobilization could be carried out If in ligamentous tears the cast is not applied until after several weeks, the ligaments will no longer reunite because they have shortened in the meantime With the common treatment of compresses massage and energetic passive movements the foot sometimes remains painful and uncertain for months or permanently, because without immobilization the torn ligaments unite in a stretched-out condition Severe general disturbances can also follow prolonged bed rest

Case history I remember a case that ended in death A 50 year old heavy woman was treated elsewhere with compresses and bed rest for a sprained ankle In the third week she developed a thrombophlebitis and after 5 weeks pulmonary embolism occurred followed by fatal pneumonia

Such complications cannot occur if the injured are rendered free from pain and able to walk by means of a suitable bandage or cast

118 FRACTURES OF THE TALUS

Classification of Fractures of the Talus These fractures can involve the body the neck, the head the posterior process or the lateral process

Occurrence Fractures of the posterior process of the talus are the commonest Next most common are those of the neck of the talus and the head of the talus Fractures of the body of the talus and of the lateral process of the talus are rare

Mechanism of Fractures of the Talus

These fractures usually are the result of impaction bending and shearing as a result of a fall or being buried by cave in etc, often in combination with fractures and dislocations of the adjoining bones and joints

Mechanism of Fractures of the Posterior Process of the Talus These fractures are seen most commonly in combination with fractures of the calcaneus when the tuberosity of the calcaneus is sheared off the posterior process of the talus is sheared off by it An angle which is open cranially is thus formed between the body of the talus and the posterior process In posterior dislocations of the foot at the talocalcaneal joint this angle is open toward the sole (fig 2791) It is also found in subtalar dislocations of the foot It should not be confused with the os trigonum the surface of which is everywhere smooth including the surface adjacent the talus The entire posterior process can be involved or only the longer fibular tubercle or the shorter tibial tubercle

Mechanism of Fractures of the Neck of the Talus These result from a fall being buried by collapsing rubble or collision with an obstacle at great speed with the ankle joint in marked dorsiflexion The sharp anterior edge of the lower end of the tibia is forced against the neck of the talus and shears it off

Mechanism of Fractures of the Head of the Talus These fractures are seen as impression and shearing fractures, for instance in dislocations of the foot at the talocalcaneal joint (figs 2855 a b)

Mechanism of Fractures of the Body of the Talus Compression fractures result of a vertical fall with the foot in pronation They are seen in combination with fractures of the calcaneus and in lateral dislocations of the foot at the talocalcaneal joint They also sometimes occur as isolated fractures

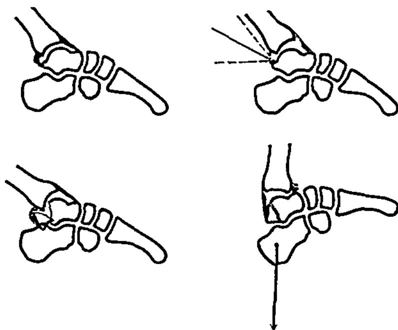
Mechanism of Fractures of the Body of the Talus Compression fractures of the body of the talus that occur as a result of a vertical fall are rare, as are fractures through the sagittal plane The latter are found only in combination with supination fractures of one or both malleoli (fig 2831 a) or with supination external rotation fractures The posterior third of the trochlea of the talus can be sheared off by forceful plantarflexion (figs 2794, 2797)

Description of the Fracture in the Neck of the Talus The fracture line extends obliquely from anterolaterally to posteromedially along the groove on the under surface of the neck of the talus

Diagnosis of Fractures of the Talus Diagnosis is possible only with good roentgenograms The lateral films usually clearly show the changes



2793 May 3 1937 2794



2795—2798
Sketched July 23 1936

Figs 2793 2794 Supination adduction fracture of both malleoli in slight varus position with shearing off of the posterior third of the trochlea of the talus This fragment has been displaced posteriorly out of the joint The concavity of the outer surface of the lateral malleolus has disappeared Sustained by a 20 year old woman when she collided with a tree as passenger in a motorcycle side car Simultaneous fracture of the neck of the talus with subtalar forward dislocation of the right foot (see figs 2803—2804)

Figs 2795—2797 —When the strongly plantarflexed and slightly supinated foot which has been traveling at relatively high speed comes to a sudden halt the tibia impinges forward against the trochlea of the talus and its posterior edge shears off the posterior third of the trochlea of the talus

Fig 2798 —If the foot is strongly dorsiflexed the posterior fragment is pulled back into proper position by the ligaments between the tibia and the talus and between the talus and the calcaneus (see fig 2800)

Treatment of Fractures of the Talus Without Displacement These fractures are treated in the same manner as malleolar fractures without displacement namely with a temporary split bed cast until the swelling has receded followed by a lower leg walking cast for an additional 5 weeks





2799 May 3 1937 2800





2801 May 18 1938 2802

Figs 2799 2800—Same case as on facing page in the screw traction apparatus The ankle joint space is somewhat pulled apart Both malleoli and the posterior fragment of the talus have been well replaced

Figs 2801 2802—Same case after a year Bony union of all three fractures in very good position At the outer border of the lateral malleolus the normal concavity at the level of the joint space which had disappeared before reduction has been restored Joint space of the ankle joint and of the talocalcaneal joint of normal width Mobility in the ankle joint is normal while that in the talocalcaneal joint is slightly limited At reexamination September 6 1955 namely after 18 years a moderate arthrosis was present a the upper part of the talocalcaneal join Ankle joint 85° to 105° as compared to 85° to 120° on the opposite side Talocalcaneal joint immobile but painless



2803 May 3 1937 2804



2805 May 18 1938 2805 a September 6 1955

FIG 2803 Fracture of the neck of the talus with forward subtalar dislocation of the foot In front at the neck of the talus a 10×8 mm bending wedge has been broken out Sustained at marked dorsiflexion by the 20 year old woman of figs 2793 2794

FIG 2804 —Same case during reduction in the screw traction apparatus The fracture is well reduced The subtalar forward dislocation of the foot is reduced The bending wedge lies on the neck of the talus Maximal plantarflexion is necessary only for reduction For immobilization the foot should be at 110° or at the most 120°

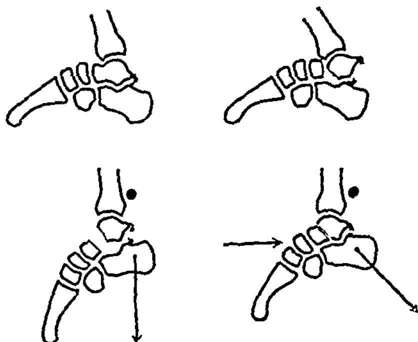
FIG 2805 Same case after a year Bony union in very good position 9 months after the injury the bending wedge that lay on the neck of the talus was removed because dorsiflexion was possible only to a right angle Mobility at the ankle joint now normal while at the talo calcaneal joint it is restricted by one third No complaints

FIG 2805 a —Same case after 18 years The trochlea of the talus has become lower The joint space of the ankle is slightly narrowed without any arthrotic lipping The roentgenogram has not been made accurately from the side but somewhat obliquely The talocalcaneal joint space is markedly narrowed Moderate lipping Minimal arthrosis at the lower anterior edge of the tibia No swelling of either leg Skin color normal Toes freely movable Talocalcaneal joints of both feet immobile No pain on attempted passive motion Ankle joint 85° to 120° as compared to 85° to 105° on the other side Gait normal without a limp Can ice skate ski and walk for hours Usually has no complaints during her work as housewife Pain only occurs when she stands all day as on washdays

Treatment of Compression Fractures of the Body of the Talus These are reduced in the screw traction apparatus and are treated in the same manner as impaction fractures at the lower end of the tibia (see 1841)

FRACTURE OF THE NECK OF THE TALUS WITH ANTERIOR DISLOCATION OF THE SUBTALAR FOOT

Mechanism Fractures of the neck of the talus with anterior dislocation of the foot at the talocalcaneal joint result from extreme dorsiflexion at the ankle as in a jump from a height, collision with an obstacle at high



2806—2809 Sketched on March 26 1928

Figs 2806 2807 When the strongly dorsiflexed and slightly supinated foot which has been travelling at relatively high speed comes to a sudden halt the sharp lower anterior edge of the tibia impinges against the neck of the talus and shears it off At the same time the posterior *ligaments between the talus and the calcaneus tear and the body of the talus together with the* tibia slides out of the joint The body of the talus can become caught behind the joint surface of the calcaneus A dorsally open angle is present between the fragments

Fig 2808 — The fragments are disengaged by strong longitudinal traction and forceful plantar flexion and the angulation between the fragments is corrected

Fig 2809 — *The forward dislocated foot is moved backwards by downward and backward* traction and simultaneous forceful plantarflexion and is then reduced by releasing the traction The maximal plantarflexion shown in figures 2804 and 2808 is decreased The same result can *be achieved by placing the ankle joint over the padded edge of a table and strongly plantar* flexing the foot (fig 2816 a)

speed, catching the foot in a crevice or being buried by falling rubble Dorsi flexion at the ankle probably occurs with simultaneous flexion of the knee and the hip The sharp anterior edge of the lower end of the tibia shears the neck of the talus off obliquely at its weakest point A bending fracture with a dorsal bending wedge results (*figs 2803, 2804, 2810 2812 2817, 2820*) Sometimes a small fragment is sheared off from the lower anterior edge of



Fig 2810 Fracture through the neck of the talus Horizontal fracture lines extend to the head of the talus The body of the talus is so strongly plantarflexed that its fracture surface is horizontal (compare fig 2807) There is marked subtalar forward dislocation of the calcaneus the head of the talus and the entire foot Sustained by a 26 year old laborer in a fall from a 3 M height catching his foot between some boards and hanging by it

Fig 2811 Same case from in front The body of the talus is in the malleolar fork The foot is slightly adducted and supinated

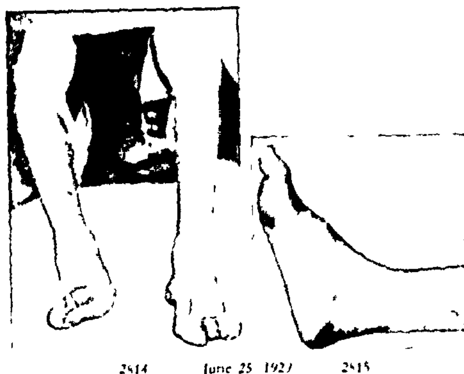


Fig 2812 Same case immediately after reduction over a wooden wedge The fragments are in good position The forward dislocation of the foot has disappeared A small bending wedge can be seen on the neck of the talus

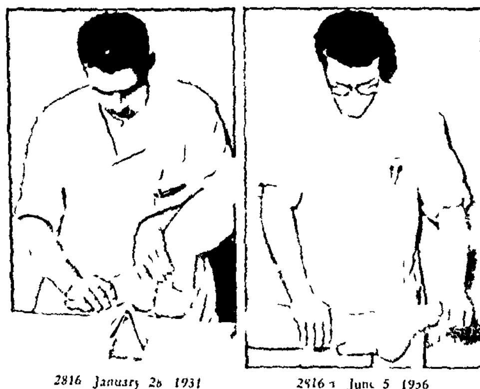
Fig 2813—Same case after 21 years The fragments of the talus have healed in such good position that the fracture lines are no longer visible The posterior process of the talus is larger and two arthrotic spurs can be seen at the points of insertion of the posterior ligaments These have not increased in size since 1936 Slight lipping at the lower anterior edge of the tibia Slight thickening in the region of the ankle joint Normal skin color no muscle atrophy Toes freely mobile Talocalcaneal joint immobile No pain on attempted passive motion Ankle joint 70° to 110° as compared to 60° to 115° on the left Gait normal No limp Pain and swelling occurs only on overexertion Continues former work as laborer No disability pension

Figs 2814 2815—Corresponding photographs to figs 2810 2811 The right foot is slightly supinated and adducted In the lateral photograph a transverse fold can be seen below the medial malleolus The terminal phalanx of the great toe is plantarflexed Because of the forward dislocation of the foot the calcaneus projects less than on the normal side and the forefoot appears longer

Fig 2816—Reduction of fracture dislocations of the talus by forceful plantar flexion over a wooden wedge that has been padded with towel The wedge is later placed under the Achilles tendon



2814 June 25 1927 2815



2816 January 26 1931 2816 a June 5 1936

FIG 2816 a – *Reduction of a fracture dislocation in the talocalcaneal joint the talonavicular joint and the Lisfranc joint The ankle joint lies over a padded table edge with the heel projecting over the edge One hand holds the tibia above the ankle and the other forces the forefoot into marked plantar flexion In this manner in fracture dislocations of the talus the dorsally open angle is corrected the fracture surface of the body of the talus is disengaged from the calcaneus and the forward dislocated foot is pushed backward and thus reduced as in figs 2808 and 2809 Rotational displacements as inward rotation (fig 2118) and outward rotation (fig 2826) can easily be replaced by lateral pressure after the talus has been disengaged from the calcaneus*



2810 June 25 1929 2811

Fig 2810 Fracture through the neck of the talus Horizontal fracture lines extend to the head of the talus The body of the talus is so strongly plantarflexed that its fracture surface is horizontal (compare fig 2807) There is marked subtalar forward dislocation of the calcaneus the head of the talus and the entire foot Sustained by a 26 year old laborer in a fall from a 3 M height catching his foot between some boards and hanging by it

Fig 2811 – Same case from in front The body of the talus is in the malleolar fork The foot is slightly adducted and supinated



2812 June 25 1929 2813 August 12 1950

Fig 2812 Same case immediately after reduction over a wooden wedge The fragments are in good position The forward dislocation of the foot has disappeared A small bending wedge can be seen on the neck of the talus

Fig 2813 Same case after 21 years The fragments of the talus have healed in such good position that the fracture lines are no longer visible The posterior process of the talus is larger and two arthrotic spurs can be seen at the points of insertion of the posterior ligaments These have not increased in size since 1936 Slight lipping at the lower anterior edge of the tibia Slight thickening in the region of the ankle joint Normal skin color no muscle atrophy Toes freely mobile Talocalcaneal joint immobile No pain on attempted passive motion Ankle joint 70° to 110° as compared to 60° to 115° on the left Gait normal No limp Pain and swelling occurs only on overexertion Continues former work as laborer No disability pension

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Fig 2816 — Reduction of fracture dislocations of the talus by forceful plantar flexion over a wooden wedge that has been padded with towel The wedge is later placed under the Achilles tendon

(figs 2814 2826 c) and less often in pronation (fig 2823) Moreover in closed fractures dorsal displacement of the peripheral fragment of one third or one half of the width of the bone occur In open fracture dislocations displacements in the frontal and sagittal planes of the full width of the bone (fig 2818) or of several times the full width of the bone (fig 2826) may occur

Plantar Displacement of the Navicular Bone Sometimes there is subluxation between the head of the talus and the navicular in the sagittal plane (figs 2810 2817) It apparently takes place after the fracture of the neck of the talus when the anterior edge of the tibia presses on the proximal end of the peripheral fragment and levers the head of the talus out of the talonavicular joint This is especially well shown in figure 2829

Clinical Diagnosis Shortening of the heel and lengthening of the fore foot is striking (figs 2815 2826 c) The foot is often more or less supinated (figs 2814 2826 c) but sometimes pronated (fig 2823) If the forward subtalar displacement of the foot is more than 1 to 5 cm the distal phalanx of the great toe is usually fixed in plantar flexion (fig 2815) because the flexor tendon of the great toe traverses a greater distance A transverse fold can often be seen to be drawn inwards under the medial malleolus in the region of the talocalcaneal joint (fig 2815)

Roentgenologic Diagnosis This fracture dislocation often escapes recognition in the roentgenogram especially when the dorsally open angle between the fragments, the dorsal displacement of the head of the talus in the sagittal plane and the subtalar dislocation are not very great as in figure 2803 The bending wedge at the dorsum of the neck of the talus should make one think of this fracture dislocation In questionable cases a comparison film should be made of the sound side

Possible Complications Following Fracture of the Neck of the Talus with Forward Dislocation of the Foot at the Talocalcaneal Joint If this fracture dislocation is not recognized or not exactly reduced and immobilized for a sufficient time, traumatic club foot or flat foot with marked limitation of motion and later painful arthrosis will develop

Treatment *Time of Reduction* Reduction is best carried out on the first day, because reduction becomes more difficult with the passage of time

Reduction over the Padded Edge of a Table We use local general or spinal anesthesia for reduction The leg is placed so that the Achilles tendon is on the padded (folded towel) edge of the table, and the foot is maximally plantar-flexed (fig 2816 a) By this maneuver the peripheral fragment is brought into the axis of the central fragment and is pulled away from the central fragment as in figure 2808 The dorsally open angle and the anterior displacement in the sagittal plane disappear At the same time the foot is forced backward as in figure 2809 Thus as a rule this anterior fracture-dislocation can be reduced with one maneuver When medial or lateral displacements in the frontal plane are present, these can be corrected without difficulty by corresponding pressure from the side Rotation can also easily be corrected Care should be taken not to overdo correction of the rotation

Roentgenograms Now roentgenograms are taken in both main planes

Reduction in the Screw Traction Apparatus When the roentgenograms show that the fracture has not been reduced by the maneuver of plantar-

the tibia At the same time the posterior ligaments between the talus and the calcaneus tear and the body of the talus together with the tibia dislocates posteriorly out of the talocalcaneal joint The foot is therefore dislocated anteriorly at the talocalcaneal joint (fig 2807) I have described these circumstances in the first case of this type that I had the opportunity to see and to treat [1] Ossification of the posterior ligaments between the talus and the calcaneus can be seen here later as evidence of the ligamentous tear

If after the production of this anterior fracture-dislocation the body turns towards the foot supination and internal rotation result and the foot assumes a more or less marked varus position (figs 2814, 2815) In the presence of especially marked varus the skin may tear (fig 2826 c) The foot is then markedly dislocated inwards and forwards

If after the production of this anterior fracture dislocation the body turns away from the foot, external rotation and pronation result and the foot assumes a valgus position (figs 2817, 2818 2823) The skin also tears in the more severe forms of dislocations of this type Supination and internal rotation or pronation and external rotation follows the dorsiflexion at the ankle in a fraction of a second Or the foot may also be in inward or outward rotation before the maximal dorsiflexion

If the foot is first supinated during the production of the fracture, a subluxation in supination or a supination fracture of the medial malleolus (fig 2828) or of both malleoli (fig 2827) with tear of the lateral ligaments and of the capsule results The neck of the talus is then sheared off by the maximal dorsiflexion of the foot that immediately follows and the body of the talus, whose ligaments are already torn, dislocates posteriorly out of the joint The result is that the body of the talus is dislocated posteriorly

Fracture dislocations of the ankle with shearing off of a ventral wedge of the tibia and anterior dislocation of the foot at the ankle (fig 2522) are caused in a manner similar to fractures of the neck of the talus with anterior dislocation of the foot at the talocalcaneal joint with the difference that in the former the posterior ligamentous attachments of the ankle joint tear first rather than those of the talocalcaneal joint as occurs with simultaneous fractures of the neck of the talus The reason that the same mechanism i e, axial impaction in dorsiflexion sometimes results in shearing off at the anterior lower end of the tibia (figs 2522 2524—2526 2535 2536) and other times in bending fractures at the neck of the talus lies perhaps in the fact that in the latter the anterior edge of the lower end of the tibia is somewhat sharper and the neck of the talus is somewhat more deeply notched

Roentgen Examination Roentgenograms of the talocrural and talonavicular joints should always be made from in front and from the side

Displacement of the Fragments The central fragment is usually more or less plantarflexed (figs 2807 2826) The two main fragments form a dorsally open angle (figs 2803 2807 2810 2817 2826) In addition they are usually twisted (dislocatio ad peripheriam) in relation to each other in supination

[1] Böhler Lorenz Die konservative Behandlung von Verrenkungsbrüchen des Sprungbeines Der Chirurg *1* 402—404 1929

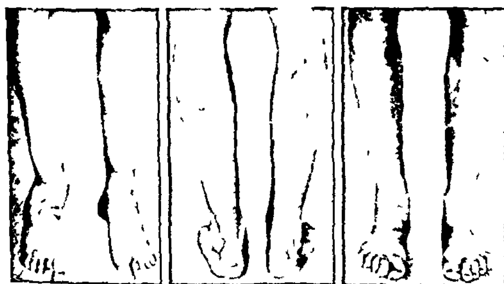
Placement of a Steinmann Pin in the Heel This should be driven in two finger breadths below the tip of the medial malleolus and not behind it If



2821 September 25 1935 2822 July 7 1954

Fig 2821 Same case after 1½ years All bones are in normal position The large dorsal bending wedge which limited dorsiflexion has been removed The dorsal surface of the head of the talus shows projecting callus

Fig 2822—Same case as in figs 2817 2820 and 2821 after 20 years The joint space of the talocalcaneal joint is somewhat narrowed There is lipping of the posterior process of the talus but less than in fig 2813 Irregular deposits are present along the dorsal surface of the talus One projects from the head of the talus The navicular shows no arthrotic changes At reexamination on July 7 1954 namely after 20 years the ankle joint is slightly thickened No significant muscle atrophy Color normal Scars soft and freely movable Plantar arch normal on both sides Mobility of the toes normal Talocalcaneal joint 70°—115° as compared to 65°—115° Gait normal without a limp Pain and swelling after vigorous activity Continues former work as laborer No disability pension Reexamined by Leitner



2823 May 24 1934 2824 2825 September 25 1935

Fig 2823—Photograph to figs 2817—2819 There is marked outward subtalar dislocation slight adduction and pronation of the foot At the medial side the skin has burst extending from the medial malleolus obliquely backward for a distance of 6 cm

Figs 2824 2825—Comparison photographs after 1½ years The form of the foot is normal The skin wound on the medial surface of the foot and the scar of the operation on the dorsum of the foot have healed with smooth freely movable scars

flexion over the padded edge of the table, the foot is placed in the screw traction apparatus The same equipment is required as for reduction of a fracture of the calcaneus



FIG 2817 Open fracture of the talus with forward and *outward* subtalar dislocation of the foot *The fragments of the talus form a dorsally open angle of 135°* A bending wedge 1 5×2 5 cm has been broken out of the neck of the talus and is in vertical position A number of small bone fragments are present at the plantar side of the fracture The body of the talus is sharply plantar flexed so that its fracture surface is directed toward the calcaneus This together with the entire foot and the head of the talus is forward and laterally dislocated Sustained by a 16 year old laborer when he caught his foot between two rolling platforms

FIG 2818 Same case from in front The talus is fractured The body of the talus lies in the malleolar fork *the foot together with the head of the talus is markedly dislocated outward and* not inward as is usually the case *Treatment* After thorough wound excision and suture of the skin manual reduction attempted Since it is not successful reduction is carried out in the screw traction apparatus as in figure 2804 2808 and 2809 Then application of a temporary cast which was split and windowed for 4 weeks and short leg walking cast for an additional 4 week



FIG 2819 —Same case Dorsoplantar exposure The lateral portion of the head of the talus is in normal relation to the navicular The medial portion appears irregular

FIG 2820 —Same case after 4½ months taken laterally The fracture has healed by bony union The vertically tilted fragment at the dorsal part of the neck of the talus prevents dorsiflexion

Placement of a Steinmann Pin in the Heel This should be driven in two finger breadths below the tip of the medial malleolus and not behind it If



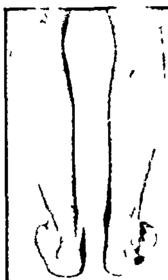


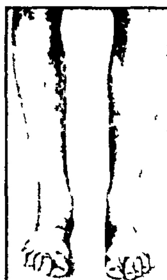
2821 September 25 1935 2822 July 7 1954

Fig 2821 Same case after $1^1/_2$ years All bones are in normal position The large dorsal lending wedge which limited dorsiflexion has been removed The dorsal surface of the head of the talus shows projecting callus

Fig 2822 Same case as in figs 2817 2820 and 2821 after 20 years The joint space of the talo calcaneal joint is somewhat narrowed There is lipping of the posterior process of the talus but less than in fig 2813 Irregular deposits are present along the dorsal surface of the talus One projects from the head of the talus The navicular shows no arthrotic changes At reexamination on July 7 1954 namely after 20 years the ankle joint is slightly thickened No significant muscle atrophy Color normal Scars soft and freely movable Plantar arch normal on both sides Mobility of the toes normal Talo calcaneal joint [illegible]°—115° as compared to 65°—115° Gait normal without a limp Pain and swelling after vigorous activity Continues former work as laborer No disability pension Reexamined by Leitner







2823 May 24 1934 2824 2825 September 25 1935

Fig 2823—Photograph to figs 2817—2819 There is marked outward subtalar dislocation slight adduction and pronation of the foot At the medial side the skin has burst extending from the medial malleolus obliquely backward for a distance of 6 cm

Figs 2824 2825—Comparison photographs after $1^1/_2$ years The form of the foot is normal The skin wound on the medial surface of the foot and the scar of the operation on the dorsum of the foot have healed with smooth freely movable scars

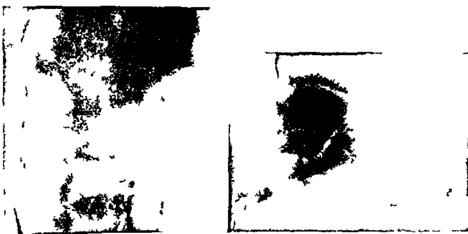
flexion over the padded edge of the table, the foot is placed in the screw traction apparatus The same equipment is required as for reduction of a fracture of the calcaneus



2817 May 24 1934 2818

Fig 2817 Open fracture of the talus with forward and *outward* subtalar dislocation of the foot The fragments of the talus form a dorsally open angle of 135° A bending wedge 1 5×2 5 cm has been broken out of the neck of the talus and is in vertical position A number of *small bone fragments are present at the plantar side of the fracture The body of the* talus is sharply plantar flexed so that its fracture surface is directed toward the calcaneus This together with the entire foot and the head of the talus is forward and laterally dislocated Sustained by a 16 year old laborer when he caught his foot between two rolling platforms

Fig 2818 Same case from in front The talus is fractured The body of the talus lies in the malleolar fork the foot together with the head of the talus is markedly dislocated outward and not inward as is usually the case *Treatment* After thorough wound excision and suture of the skin manual reduction attempted Since it is no successful reduction is carried out in the screw traction apparatus as in figure 2804 2808 and 2809 Then application of a temporary cast which was split and windowed for 4 weeks and short leg walking cast for an additional 4 week



2819 May 24 1934 2820 October 3 1934

Fig 2819—Same case Dorsoplantar exposure The lateral portion of the head of the talus is in normal relation to the navicular The medial portion appears irregular

Fig 2820—Same case after 4½ months taken laterally The fracture has healed by bony union The vertically tilted fragment at the dorsal part of the neck of the talus prevents dorsiflexion

apparatus (fig. 2942 b) and a longitudinal pull of 5 to 10 Kg. is exerted in the axis of the tibia. Thus the calcaneus is freed from the fractured body of the talus (fig. 2808). If the foot is now strongly plantarflexed the displacement in the sagittal plane and usually also that in the frontal plane disappears (figs. 2804, 2808). Otherwise it can be corrected by slight lateral pressure



2826 c June 11 1935

Fig. 2826 c. Photograph to fig. 2826. Large burst wound behind the lateral malleolus. The joint surface of the trochlea of the talus which has been soiled with sand lies exposed in the wound. The foot is angulated 30° in supination and rotated inward. *Treatment*: Careful wound excision under local anesthesia and removal of the badly soiled body of the talus. Then after insertion of a drain for 24 hours the skin was closed without bursting sutures or ligatures. Temporary cast for 5 weeks split and windowed. Then walking cast for an additional 7 weeks.

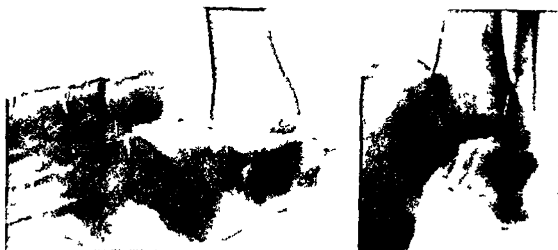


2826 d January 15 1936

Fig. 2826 d. Photographs to figs. 2826 a and 2826 b and comparison to fig. 2826 c after 7 months. Ankle joint thickened. Malleoli at a lower level. Fine freely movable scar. Motion at ankle joint markedly limited. Walking still painful. Had to walk with the aid of a cane for the first 3 years after which there was gradual improvement. At follow up examination after 15 years by Leitner the talus showed no particular swelling. The scar was smooth and freely movable. Toes freely movable. Mobility of the foot on the lower leg 80° to 95° as compared to 70° to 100° on the right. Walks without a limp. Pain occurs after 2 to 3 hours walking and standing. Continues former work as laborer. Draws 40/ disability pension.

it is driven in further posteriorly as for fractures of the shaft of the tibia or through the upper portion of the tuber calcaneus as in fractures of the calcaneus, the foot will be dorsiflexed by the longitudinal traction *Plantar flexion* is however necessary for reduction of this fracture dislocation

Reduction After the roentgenograms have been so placed that they can be well seen during the reduction, the leg is placed on the screw traction



2826 June 11 1935



2826 a January 15 1936 2826 b June 5 19 0

Fig 2826 – *Open* fracture of the neck of the talus with complete forward and inward dislocation of the foot Sustained by a 33 year old laborer in a cave in of a sand pit In the lateral roentgenogram the body of the talus is subluxated posteriorly and plantar flexed 90° The foot is displaced so far forward and upward that the posterior margin of the calcaneus is in front of the trochlea of the talus and at the level of the malleolar fork In the anterior view the head of the talus together with the entire foot is displaced medially and upward by its full width

Fig 2826 a Same case after 7 months The body of the talus has been removed The tibia rests on the head of the talus and on the calcaneus

Fig 2826 b – Same case after 15 years The anterior part of the tibia rests on the head of the talus Its shape has changed so that it resembles the trochlea of the talus The joint between the head of the talus and *the navicular shows marked* arthrotic changes Reexamination by Leitn r

described by Krosl [1] Usually arthrotic lipping and spurring developed at the dorsum of the talocalcaneal joint (figs 2805a 2813, 2822) In spite of this there was usually no pain and prolonged walking was possible

Treatment of Open Fractures of the Neck of the Talus with Anterior, Medial or Lateral Dislocation of the Foot Below the Body of the Talus

In all open fracture dislocations the wound must be carefully excised in the manner described in Vol I pp 149—174 Then the fracture dislocation is reduced and, after drain is inserted that is to remain for 24 hours the skin is closed without burying sutures or ligatures In fresh wounds that are not older than 8—10 hours the body of the talus and the head of the talus should not be removed even when they are markedly soiled They can always be cleaned with hammer and chisel and with a rongeur The fragments should only be removed when the wound is already markedly infected If it is at all possible the bones should be left in place and later if necessary an arthrodesis should be made According to our experience patients in whom the talus has been removed have severe disability lasting 2—4 years Later there is some improvement Walking is however, usually possible with an orthopedic shoe or with an orthopedic brace

Treatment of Old Fractures of the Talus with Anterior Dislocation of the Foot Below the Body of the Talus

If these fracture dislocations are not reduced or if they are immobilized in marked supination as in figure 2661 healing takes place in a club foot position and walking is painful and difficult In such cases an approximately normal shaped foot should be achieved by wedge osteotomies as in figures 2774—2779 The bones are fixed with crossed Kirschner wires after the operation Then a temporary bed cast is applied and after 2 to 3 weeks a lower leg walking cast for an additional 10 weeks

Questions One Should Ask Oneself in Order to Avoid Complications in the Treatment of Fractures of the Neck of the Talus with Forward Dislocation of the Foot Under the Body of the Talus

1 Have I obtained good roentgenograms of the ankle joint and of the talonavicular joint?
2 Have I particularly looked for an angulation with a dorsally open angle in the lateral roentgenogram and for lateral displacements in both roentgenograms?
3 Have I in unclear cases obtained roentgenograms of the sound side for comparison?
4 Have I determined clinically whether shortening of the heel and lengthening of the forefoot is present?
5 Have I determined if displacement in the frontal plane and also rotation

[1] Krosl W Gleichzeitiger beiderseitiger Bruch des Sprungbeinhalses mit Verrenkung des Fußes unter dem Sprungbeinkorper nach vorne Arch orthop u Unfall Chir 49 1957

When traction is decreased to 4 to 5 Kg, the fragments of the talus approximate themselves (figs 2804, 2809)

Roentgen Check and Removal of the Steinmann Pin from the Heel When the roentgenograms show that the fracture dislocation has been well reduced the Steinmann pin is carefully withdrawn and a cast is applied

Immobilization The temporary lower leg bed cast is applied with the leg dependent and the knee at right angle flexion and with the ankle joint at 110° to 120° (figs 2644—2648), as for a malleolar fracture (see p 1920) The plantarflexion must be 10° to 15° less than maximal plantarflexion of the sound side It is expedient that the surgeon himself hold the foot during *the application of the cast and that someone else apply the cast*

We have seen a patient with this injury in whom the cast was applied at a plantarflexion of 160° Overcorrection resulted with severe discomfort later requiring arthrodesis

Roentgen Check After application of the cast new roentgenograms are obtained in both planes

Aftercare When the roentgenograms show good position, the cast must be split through its last thread along the cord that has been included for that purpose, in order to avoid interference with circulation The leg is then placed on a Braun splint and further care is as described on page 1927

Application of the First Lower Leg Walking Cast When the swelling has receded after 8 to 10 days a short leg walking cast is applied at plantar flexion of 110° to 120° and a walking stirrup applied as described on page 1928 If the cast is applied in less plantarflexion there is risk of redislocation

Roentgen Check After application of the first short leg walking cast, roentgenograms must be made in both planes

Application of the Second Lower Leg Walking Cast The first short leg walking cast can be removed 4 to 5 weeks after reduction After carefully dorsiflecting to approximately 100° a new short leg walking cast is applied If the angle of plantarflexion is reduced too early as for example after a week, angulation may occur at the neck of the talus and the foot may redislocate anteriorly

Roentgen Check After the application of the second lower leg walking cast new roentgenograms are made in both planes and later every 2 weeks

Duration of Immobilization The second lower leg walking cast is removed 10 weeks after the injury

Exercises and Aftercare are carried out as for fractures of the malleoli (see p 1928)

Operative Reduction We have always been succesful in reducing and maintaining reduction of this fracture-dislocation without operation We have therefore never resorted to osteosynthesis for example with screws

Results Mobility in the talocalcaneal joint is often sharply reduced or absent, while mobility of the ankle joint is only slightly restricted We have had a case with a severe fracture-dislocation of the neck of the talus of both sides in which both talocalcaneal joints were freely mobile It has been

23 Have I measured the angle between the sole of the foot and the leg with a goniometer?
24 Have I obtained new roentgenograms in both planes after the application of the cast?
25 Have I split the cast through the last thread along the cord in order to avoid disturbances in circulation?
26 Have I after the swelling has receded namely in 8 to 10 days in closed fracture dislocations, applied the first lower leg walking cast at plantar flexion of 110° to 120°?
27 Have I on removal of the temporary cast been particularly careful to avoid dorsiflexion of the foot in order that it does not redislocate?
28 Have I obtained roentgenograms from both sides after the application of the first lower leg walking cast?
29 Have I applied the second lower leg walking cast at about 100° plantarflexion 4 to 5 weeks after reduction?
30 Have I obtained new roentgenograms after application of the second lower leg walking cast?
31 Have I removed the second lower leg walking cast 10 weeks after the injury?
32 Have I in open fractures thoroughly debrided the body of the talus and the head of the talus with a rongeur or with hammer and chisel and removed them only if the patient was not seen until late and the wound was already markedly infected?

FRACTURES OF THE NECK OF THE TALUS WITH POSTERIOR DISLOCATION OF THE BODY OF THE TALUS

Mechanism This fracture dislocation results from falls from a height (in fact in 3 of our first 4 cases it resulted from a fall from a ladder), from being buried by rubble, or from collision at high speed with an obstacle, as for instance with a motorcycle an auto or an airplane When under these circumstances the slightly supinated foot strikes the ground or the obstacle the lateral ligaments of the ankle joint and sometimes of the talocalcaneal joint tear as a result of the sharply increased supination, and a supination subluxation or more often a supination fracture of the medial malleolus (fig 2828) or of both malleoli (fig 2627) results We have seen one case in which this injury has resulted from pronation and abduction with fracture of the lateral malleolus and tear of the deltoid ligament after lateral subluxation at the ankle joint Following the supination or pronation mechanism almost simultaneously a shearing and bending fracture occurs at the neck of the talus and the body of the talus dislocates posteriorly, because the ligaments have already torn following the excessive supination or pronation The head of the talus is sometimes displaced dorsally (fig 2828)

In contrast in fracture of the neck of the talus with forward and medial dislocation of the foot (fig 2626) the fracture of the neck of the talus occurs first then the forward dislocation of the foot and finally the medial displacement as the result of internal rotation (fig 2826 c)

of the forefoot around the longitudinal axis of the tibia (internal or external rotation) and around the longitudinal axis of the foot (supination or pronation) are present in addition to the displacement in the sagittal plane?

6 Have I observed whether flexion of the terminal phalanx of the great toe is present (fig 2815)? In closed fracture-dislocations this is a sign that the foot is displaced more than 1 5 cm anteriorly under the body of the talus

7 Have I under local, general or spinal anesthesia reduced the fracture-dislocation over the edge of a table which has been padded with a folded towel by forceful plantarflexion of the fore foot?

8 Have I reduced displacements in the frontal plane by slight lateral pressure after the fragments have been disengaged?

9 Have I avoided overcorrection of rotational displacement in the longitudinal axis of the foot (supination or pronation)?

10 Have I obtained roentgenograms in both planes after reduction?

11 Have I driven a Steinmann pin through the middle of the body of the calcaneus 2 cm below the medial malleolus if reduction over the padded edge of a table was not successful?

12 Have I avoided driving the Steinmann pin through the posterior half of the body of the calcaneus as for fractures of the tibia or through the upper portion of the tuber calcanei as for fractures of the calcaneus, because the foot would then be dorsiflexed by the traction whereas plantarflexion is required?

13 Have I placed the leg on the short screw traction apparatus after the proper insertion of the Steinmann pin (fig 2942 b)?

14 Have I then applied longitudinal traction of 8 to 10 Kg to the properly placed Steinmann pin?

15 Have I plantarflexed the forefoot after disengaging the calcaneus from the talus in order to straighten the dorsally open angle and to correct displacement in the sagittal plane (figs 2804 2808)?

16 Have I after straightening of the angulation and correction of the displacement in the sagittal plane also corrected a displacement in the frontal plane by slight lateral pressure?

17 Have I then reduced the traction to 4 to 5 Kg ?

18 Have I forced the foot backward in order to reduce the anterior dislocation of the foot under the body of the talus?

19 Have I then obtained roentgenograms from both sides?

20 Have I carefully removed the Steinmann pin from the calcaneus if the roentgenograms showed good position?

21 Have I applied a temporary lower leg cast with the knee in right angle flexion and the ankle flexed to 110° to 120° and the foot in mid-position between pronation and supination when the roentgenograms showed good position after reduction?

22 Have I personally held the foot in proper position while someone else applied the cast?

23 Have I measured the angle between the sole of the foot and the leg with a goniometer?
24 Have I obtained new roentgenograms in both planes after the application of the cast?
25 Have I split the cast through the last thread along the cord in order to avoid disturbances in circulation?
26 Have I after the swelling has receded, namely in 8 to 10 days in closed fracture-dislocations, applied the first lower leg walking cast at plantar flexion of 110° to 120°?
27 Have I on removal of the temporary cast been particularly careful to avoid dorsiflexion of the foot in order that it does not redislocate?
28 Have I obtained roentgenograms from both sides after the application of the first lower leg walking cast?
29 Have I applied the second lower leg walking cast at about 100° plantar-flexion 4 to 5 weeks after reduction?
30 Have I obtained new roentgenograms after application of the second lower leg walking cast?
31 Have I removed the second lower leg walking cast 10 weeks after the injury?
32 Have I in open fractures thoroughly debrided the body of the talus and the head of the talus with a rongeur or with hammer and chisel and removed them only if the patient was not seen until late and the wound was already markedly infected?

FRACTURES OF THE NECK OF THE TALUS WITH POSTERIOR DISLOCATION OF THE BODY OF THE TALUS

Mechanism This fracture-dislocation results from falls from a height (in fact in 3 of our first 4 cases it resulted from a fall from a ladder), from being buried by rubble, or from collision at high speed with an obstacle, as for instance with a motorcycle, an auto or an airplane When under these circumstances the slightly supinated foot strikes the ground or the obstacle the lateral ligaments of the ankle joint and sometimes of the talocalcaneal joint tear as a result of the sharply increased supination, and a supination subluxation or more often a supination fracture of the medial malleolus (fig 2828) or of both malleoli (fig 2827) results We have seen one case in which this injury has resulted from pronation and abduction with fracture of the lateral malleolus and tear of the deltoid ligament after lateral subluxation at the ankle joint Following the supination or pronation mechanism almost simultaneously a shearing and bending fracture occurs at the neck of the talus and the body of the talus dislocates posteriorly, because the ligaments have already torn following the excessive supination or pronation The head of the talus is sometimes displaced dorsally (fig 2828)

In contrast in fracture of the neck of the talus with forward and medial dislocation of the foot (fig 2826) the fracture of the neck of the talus occurs first, then the forward dislocation of the foot and finally the medial displacement as the result of internal rotation (fig 2826 c)

of the forefoot around the longitudinal axis of the tibia (internal or external rotation) and around the longitudinal axis of the foot (supination or pronation) are present in addition to the displacement in the sagittal plane?

6 Have I observed whether flexion of the terminal phalanx of the great toe is present (fig 2815)? In closed fracture-dislocations this is a sign that the foot is displaced more than 1 5 cm anteriorly under the body of the talus

7 Have I under local, general or spinal anesthesia reduced the fracture-dislocation over the edge of a table which has been padded with a folded towel by forceful plantarflexion of the fore foot?

8 Have I reduced displacements in the frontal plane by slight lateral pressure after the fragments have been disengaged?

9 Have I avoided overcorrection of rotational displacement in the longitudinal axis of the foot (supination or pronation)?

10 Have I obtained roentgenograms in both planes after reduction?

11 Have I driven a Steinmann pin through the middle of the body of the calcaneus 2 cm below the medial malleolus if reduction over the padded edge of a table was not successful?

12 Have I avoided driving the Steinmann pin through the posterior half of the body of the calcaneus as for fractures of the tibia or through the upper portion of the tuber calcanei as for fractures of the calcaneus, because the foot would then be dorsiflexed by the traction whereas plantarflexion is required?

13 Have I placed the leg on the short screw traction apparatus after the proper insertion of the Steinmann pin (fig 2942 b)?

14 Have I then applied longitudinal traction of 8 to 10 kg to the properly placed Steinmann pin?

15 Have I plantarflexed the forefoot after disengaging the calcaneus from the talus in order to straighten the dorsally open angle and to correct displacement in the sagittal plane (figs 2804 2808)?

16 Have I after straightening of the angulation and correction of the displacement in the sagittal plane also corrected a displacement in the frontal plane by slight lateral pressure?

17 Have I then reduced the traction to 4 to 5 kg ?

18 Have I forced the foot backward in order to reduce the anterior dislocation of the foot under the body of the talus?

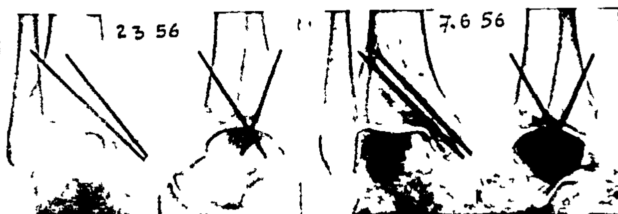
19 Have I then obtained roentgenograms from both sides?

20 Have I carefully removed the Steinmann pin from the calcaneus if the roentgenograms showed good position?

21 Have I applied a temporary lower leg cast with the knee in right angle flexion and the ankle flexed to 110° to 120° and the foot in mid position between pronation and supination when the roentgenograms showed good position after reduction?

22 Have I personally held the foot in proper position while someone else applied the cast?





2828—2828 b

Fig 2828 —Open fracture dislocation of the talus and partial dislocation of the head of the talus Sustained by a 49 year old bricklayer in a 4 M fall from a slipping ladder The talus is fractured at the neck The body of the talus is displaced medially by half its width dorsally by its full width and cranially by approximately double its width It is rotated approximately 45° about its vertical axis and tipped The fracture surface faces backward and inward The head of the talus is dorsally subluxated by half of its width The medial malleolus is broken off and its shadow can be seen in the middle of the ankle joint The foot is rotated 90° inward and is pronated because the first and fifth metatarsals are superimposed as contrasted with the supinated foot in fig 2826 in which they are seen side by side A 15 cm laceration is present on the medial surface that extends from the mid point of the ankle joint in front backward over the medial malleolus to reach the insertion of the Achilles tendon Pulse not palpable Sensibility decreased A 5 cm bony hard protrusion can be seen and felt in front of the ankle joint *Treatment* Accurate wound excision and cleaning of the soiled fracture surfaces with a rongeur A Steinmann pin is driven through the middle of the body of the calcaneus as in fig 2800 2804 2808 Forcible longitudinal traction on the pin by means of a stirrup and outward rotation of the foot Rontgenograms in both planes show that the fragments are in good position Thereupon fixation of the medial malleolus with two crossed Kirschner wires and suture of the skin alone without burying sutures or ligatures Temporary long cast that is immediately split and windowed After 2 weeks a 30×70 mm area of apparent superficial skin necrosis that separates after 4 weeks The wound rapidly becomes smaller with treatment by exposure so that on April 27 a closed lower leg walking cast can be applied

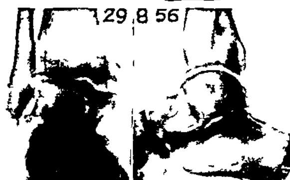
Fig 2828 a —Same case following the placement of the crossed Kirschner wires Very good position in both views

Fig 2828 b —Same case after 14 weeks Position unchanged Body of the talus partially dense









2827 a—d

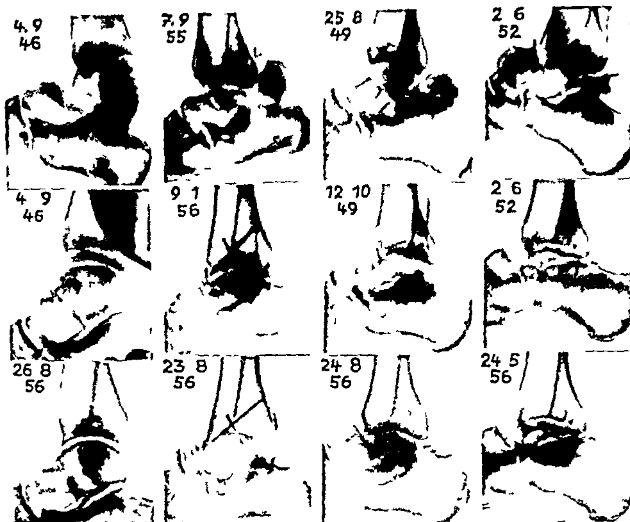
FIG 2827 a above —Fracture of the talus with dislocation of the foot forwards and somewhat laterally and of the body of the talus posteriorly Region of the ankle joint thickened Sustained by a 14 year old apprentice who slipped 3 M from a ladder landed on his heels and fell forwards Foot displaced laterally Two transverse folds anterolaterally over the ankle joint Under the medial malleolus is a transverse fold similar to that in fig 2815 The foot is slightly dorsiflexed A swelling is seen in the region of the Achilles tendon instead of a concavity The terminal phalanx of the great toe is maximally flexed

FIG 2827 b middle —Fracture through the neck of the talus with dislocation of the foot together with the head of the talus 3 cm forward The posterior margin of the calcaneus is in line with *the dorsal surface of the tibia* The anterior portion of the medial malleolus which is broken off in the frontal plane can be seen overlying the space between the body of the talus and the head of the talus The lateral malleolus is displaced into varus position at the epiphyseal line The body of the talus is displaced dorsally and medially by half its width and rotated about its vertical axis so that *its fracture surface faces forward and outward*

FIG 2827 c lower left —Same case following reduction by longitudinal traction plantarflexion of the foot and pressure on the dislocated body of the talus with the thumb

FIG 2827 d lower right —Same case after 10 years No arthrosis evident in the talocalcaneal joint Good mobility and normal usability *No complaints The photographs and roentgenograms* are in part taken from a publication by Ender[1]

[1] Ender J Über einen konservativ behandelten V ... des Spr ... 196 1956



2830 2830 a 2830 b 2830 c

Fig 2830 above Fracture of the neck of the talus and the medial malleolus Backward dislocation of the body of the talus and forward dislocation of the calcaneus together with the foot and the head of the talus

Fig 2830 middle Same case following nonoperative reduction in the screw traction apparatus with a Steinmann pin through the calcaneus (fig 2942 b)

Fig 2830 below Same case after 10 years Bony union in good position with normal function and nearly normal mobility Arthrotic lipping of the anterior margin of the tibia

Fig 2830 a above Comminuted fracture of the neck of the talus with posterior dislocation of the body of the talus The calcaneus together with the head of the talus and the entire foot is dislocated backward

Fig 2830 a middle Same case Because of the comminution a primary arthrodesis was carried out after reduction

Fig 2830 a below – Same case after 1 year The arthrodesis is consolidated Does farm work as before the injury The first steps in the morning are disagreeable Thereafter he has no complaints

Fig 2830 b above – Fracture of the neck of the talus with backward dislocation of the body of the talus

Fig 2830 b middle – Same case The body of the talus was removed and the head of the talus left in place as in fig 2826 a

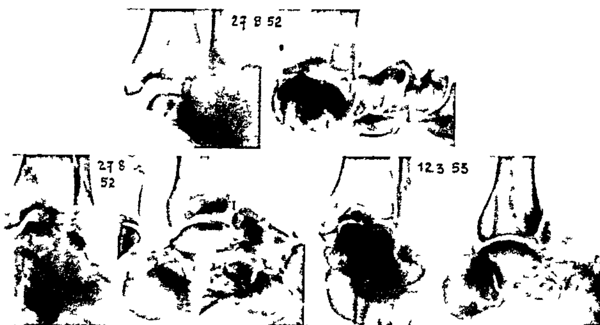
Fig 2830 b below Same case after 7 years The tibia is closer to the calcaneus Has pain after a half hour's walking Limps somewhat

Fig 2830 a above – Fracture of the neck of the talus with backward dislocation of the body of the talus and dislocation forward and upward of the head of the talus Accordingly this represents complete dislocation of the talus in the presence of fracture of the neck of the talus

Fig 2830 c middle – Same case Body and head of the talus were removed as in fig 2934

Fig 2830 c below – Same case after 4 years The position of the tibia in relation to the calcaneus remains unchanged Always has considerable pain on walking

Clinical Diagnosis In addition to the history of a fall with subsequent severe pain and inability to bear weight on the foot there is marked swelling in the region of the ankle joint The foot is sometimes displaced forwards so that the forefoot appears lengthened and the heel shortened (fig 2827) There may be simultaneous lateral or more often medial displacement of the foot The terminal phalanx of the great toe is often maximally plantarflexed (fig 2827) At the medial or lateral side of the Achilles tendon a prominence is usually seen and the dislocated body of the talus is palpable The skin is



2829—2829 b

Fig 2829—Severe *open* fracture dislocation of left talu and calcaneus Sustained in a four story fall by a 160 cm tall 29 year old bricklayer who weighed 50 kg Sustained a simultaneous open fracture dislocation of the right talus with dislocation of the body of the talus a supination fracture of both malleoli and a 6×12 cm wound over the lateral malleolus as well as a perilunar fracture dislocation of the righ wrist The skin burst transversely at the left portion of the sole The talus is fractured through its neck The body of the talus is so far plantar flexed that the ankle joint space appears widened The head of the talus is tipped up in relation to the navicular and is partially dislocated The anterior one third of the calcaneus is sheared off comminuted and dislocated in relation to the cuboid The foot is displaced laterally by its full width and forward by 3 cm and is so markedly pronated that the shadow of the body of the talus is superimposed on that of the calcaneus in the lateral roentgenogram The tip of the lateral malleolus extends to the sole *Treatment* After treatment of the severe shock the wound on the sole was carefully excised and sutured and the fracture dislocation manually reduced

Fig 2829 a—Same case after reduction The marked pronation of the foot and the forward dislocation of the foot have been largely corrected The dislocation between the head of the talus and the navicular and between the anterior portion of the calcaneus and the cuboid are reduced The dorsal displacement of the neck of the talus in relation to the body of the talus was not corrected because the skin was too tightly stretched

Fig 2829 b—Same case after 6½ months The position has remained more or less unchanged There is apparently a pseudarthrosis of the calcaneus Walking possible only with crutches because of the even more severe injury of the other leg Died 3 months later from a brain abscess

necessary to fix it with screws If the medial malleolus is fractured, it should be fixed with two crossed Kirschner wires (fig 2828)

Operative Removal of the Fragments In our first two cases we removed the fragments, because formerly most surgeons claimed that the results following excision of the talus were good Some were in favor of complete removal of the talus (fig 2830 c) while others suggested that the head of the talus be left in place (fig 2830 b) Unfortunately we found that the results in our cases with both methods were equally unsatisfactory In the more recent investigation uniformly poor results are reported following this mutilating operation Therefore we do not remove the fragments even in open injuries (fig 2828) if severe infection has not yet developed

Immobilization in plaster and aftercare is carried out as for malleolar fractures and fractures of the neck of the talus with forward dislocation of the foot under the body of the talus (see pp 1920—1932)

Duration of Immobilization In the case pictured in fig 2827 we continued immobilization in a plaster cast for 5 5 months In the patient pictured in figure 2828, who is still under treatment, we plan to continue immobilization as long He has been bearing weight since the third month

Necrosis of the Body of the Talus After operative reduction the body of the talus usually becomes denser (fig 2828) In spite of this it may retain its shape for years Sometimes it sinks together somewhat as in fig 2805 a

Arthroses seem to develop after all fracture dislocations of the body of the talus They are usually more severe in the talocalcaneal joint than in the ankle joint In spite of this symptoms may remain mild or may be completely absent as in the case of figure 2827 after an observation period of 10 years

Arthrodesis If arthrosis with severe pain develops, late arthrodesis of the talocrural and talocalcaneal joints should be carried out (see pp 1980—1988) If the body of the talus is comminuted, a primary arthrodesis should be carried out as in figure 2830 a

Results In the patient of figure 2827 the result is good after 10 years He performs street duty as a policeman and takes part in all sports Nothing can as yet be reported about the patient of figure 2828 In the patient of figure 2830 a walking was painless after a year with ankylosis at the talocrural and talocalcaneal joints at 100° He was able to carry out all of his duties as a farmer

FRACTURES OF THE BODY OF THE TALUS WITH POSTERIOR DISLOCATION OF THE POSTERIOR FRAGMENT WITHOUT FRACTURE OF THE NECK OF THE TALUS

Mechanism In one case I have seen the posterior third of the body of the talus to be sheared off with a simultaneous supination fracture of both malleoli (figs 2793 2794) when a woman collided with a tree as passenger in a motorcycle side car This fracture-dislocation probably resulted from the sudden halt of the strongly plantarflexed and slightly supinated foot which had been traveling at relatively high speed The sharp posterior edge of the lower end of the tibia thus impinged against the trochlea of the talus and sheared off the posterior third (figs 2795—2797) Usually a posterior wedge

tightly stretched over the prominence and often white and bloodless If not rapidly reduced blisters form within a few hours and black patches occur as sign of necrosis Later an ulcer develops at that point in which the displaced bone is exposed The posteriorly displaced body of the talus may press on the neurovascular bundle or may tear it and this may lead to gangrene of the forefoot in delayed reduction

Roentgen Examination Roentgenograms of the ankle joint and of the talonavicular joint should always be made in both planes In addition to the fracture of the neck of the talus and the posterior dislocation of the body of the talus, a supination fracture of the medial malleolus (fig 2828) or of both malleoli (fig 2827) is usually seen The dislocated body of the talus is usually rotated about its vertical axis so that its fracture surface faces forward and medially and the trochlea of the talus is nearly transverse in the lateral film (fig 2828)

Possible early complications such as pressure necrosis of the skin over the displaced body of the talus with infection of the joint and gangrene of the toes and the forefoot from pressure on the vessels in delayed reduction have been described above under 'clinical diagnosis'

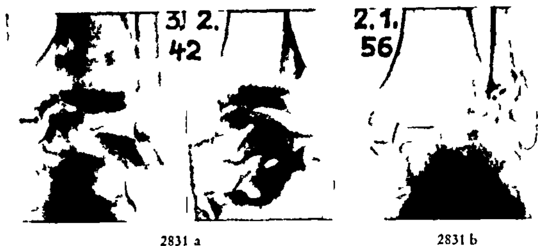
Possible late complications are pseudarthroses of the medial malleolus (fig 2827), if it is not surgically fixed as in figure 2828 Later one sometimes sees avascular necrosis of the body of the talus (fig 2828 b) and usually arthroses in the ankle joint and in the talocalcaneal joint These however may not cause any significant symptoms

Treatment *Time of Reduction* Because of the danger of skin necrosis and gangrene of the toes which may already appear in a few hours, one must perform the reduction as early as possible

Reduction in the Screw Traction Apparatus Since the calcaneus has approached the lower end of the tibia (fig 2827) or lies cranial from it after the dislocation (fig 2828), it must be pulled away from it to make room for the body of the talus For reduction a Steinmann pin is driven into the midle of the calcaneus as for dentate fractures of the neck of the talus with forward dislocation of the foot under the body of the talus (fig 2111) and the leg is placed on the short screw traction apparatus (fig 2942 b) In the case pictured in figure 2827 it was possible with 16 Kg traction to replace the body of the talus by pressure of the thumb Traction should not be increased beyond 25 Kg because the tendons are then too tense and grip the body of the talus so that it cannot be freed Leitner has found only 3 cases in the world literature in which nonoperative reduction was possible

Operative Reduction When reduction is not achieved with the screw traction apparatus, the Steinmann pin in the calcaneus is left in place in order that traction may be exerted on it during the operation Then a medial incision is made between the Achilles tendon and the tibia beginning 6 to 7 cm above the tip of the malleolus and curving forward below the fracture of the medial malleolus When the usually fractured medial malleolus is pulled downwards, the dislocated body of the talus which is usually trapped among the tendons can usually be freed by displacing the foot posteriorly and then replaced in the joint by appropriate longitudinal traction and sometimes by bending and rotating It usually then remains in place so that it is not

Treatment Reduction was carried out by longitudinal traction in the screw traction apparatus (fig 2942 b) with the ankle in dorsiflexion The Steinmann pin was driven through the dorsal portion of the calcaneus and not through its middle Figures 2798—2800 show how the broken off and posteriorly dislocated fragment was replaced by means of the traction of the posterior ligaments The result of the successful reduction after one year can be seen in figs 2801, 2802



2831 a 2831 b

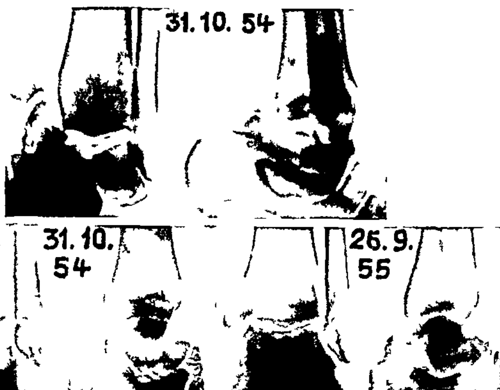
Fig 2831 a—Supination adduction fracture of the medial malleolus and sagittal split fracture of the talus as well as fracture of the neck of the talus Sustained by a 35 year old telegraph worker who was thrown from a railroad car in a collision The body of the talus is sagittally split through its middle The medial malleolus is sheared off and displaced about 6 mm cranially together with the medial fragment of the body of the talus The lateral fragment is laterally rotated about is vertical axis so that the joint surface of the trochlea of the talus lies against the lateral malleolus In the lateral view the lateral fragment can be seen also to be subluxated posteriorly No reduction carried out Not seen by us until 3 months after injury Therefore arthrodesis was performed

Fig 2831 b—Supination external rotation fracture of the lateral malleolus and sagittal split fracture of the body of the talus producing a 2 mm step between the fragments It was probably produced because the talus subluxated laterally after the fracture of the lateral malleolus and tear of the deltoid ligament and then marked valgus position resulted from axial impaction A bone shadow can be seen at the tip of the medial malleolus evidence that the deltoid ligament was avulsed at this point

SAGITTAL SPLIT FRACTURE OF THE BODY OF THE TALUS AND FRACTURE OF THE NECK OF THE TALUS WITH MEDIAL OR LATERAL DISLOCATION OF THE FOOT

Mechanism In a fall from a moderate height with the foot in supination a supination fracture of the medial malleolus or of both malleoli results The talus together with the medial malleolus usually slips over the medial edge of the fractured tibia medially and cranially to a greater or lesser degree (figs 2683 2686 a, 2734) In rare cases as the result of sudden longitudinal impaction the body of the talus is sagittaly split and sheared off by the medial edge of the fractured tibia *At the same time the neck of the talus is fractured* The medial portion of the body of the talus together with the entire foot is dislocated medially and cranially while the lateral part either remains attached

is sheared off from the lower end of the tibia as a result of longitudinal impaction in maximal plantar flexion (figs 2521, 2523, 2537, 2538) At the same time the patient sustained a fracture of the neck of the talus with forward dislocation of the foot under the body of the talus on the opposite leg (figs 2803—2809)



2831

Fig 2831 above—Supination adduction fracture of the medial malleolus Sagittal split fracture of the body of the talus and fracture of the neck of the talus Sustained by a 23 year old student in a fall from a height of 12 M during a mountain climbing excursion The body of the talus is sagittally split through its middle The medial malleolus is medially sheared off The medial fragment of the body of the talus is displaced medially and cranially together with the medial malleolus while the lateral fragment is tilted slightly into valgus position In the lateral view the medial malleolus and the medial portion of the body of the talus can be seen to be displaced dorsally while the lateral part is located ventral from the joint in the region of the head of the talus which in turn maintains its normal position in relation to the navicular *Treatment* Insertion of a Steinmann pin through the calcaneus and reduction in the screw traction apparatus (fig 2942 b)

Fig 2831 left below—Same case in cast and extension The joint is well reduced The outline of the talus is good in both planes The middle fragment of the body of the talus remains depressed In the lateral view nothing can be seen of the fracture lines Treated by cast and traction of 3 Kg to the Steinmann pin through the calcaneus for 4 weeks and then with 4 Kg for an additional 8 weeks Then lower leg cast without weight bearing for an additional 3 months Currently we would fix the medial malleolus with two crossed Kirschner wires inserted percutaneously as in fig 2734 a

Fig 2831 below right—Same case after 10 months Bony union in slight varus position because traction of 3 Kg was insufficient The defect in the body of the talus has largely been filled Talocalcaneal joint immobile ankle joint 75° to 90° as compared to 70° to 115° on the right Has again taken part in extensive mountain climbing excursions In July 1956 reported that he has done much skiing without complaints and in summer as leader of a youth group has climbed five peaks that were higher than 3000 M without symptoms referable to the injury

Mechanism This injury results from falls (fig 2832—2834), being struck by heavy objects or by a vehicle (fig 2835) etc, when the foot is suddenly forced into strong plantar flexion, supination and internal rotation with great force and rapidity As a result the ligaments on the dorsal side of the talonavicular and the lateral side of the talocalcaneal and talocrural joints tear, and dislocation of the foot under the talus and then almost simultaneously a partial dislocation in supination in the talocrural joint occur (fig 2832) As a result of the continuing action of the dislocating force the talus is torn from its ligamentous attachments and displaced to a greater or lesser degree Often the skin at the lateral side of the ankle tears in front of the lateral malleolus (fig 2834 below) The talus then lies in front of the lateral malleolus The head of the talus faces the joint while the body is lateral and anterior (fig 2834 middle) The talus may also remain in the malleolar fork at 40° supination (fig 2832 a) or at 70° supination (fig 2833 a) In figure 2833 it lies in the malleolar fork in 90° inward rotation

Complete dislocation of the talus can also result from supination adduction-inward rotation at the talocalcaneal joint and supination at the talocrural joint The body of the talus then comes to lie behind the medial malleolus and the head of the talus faces downwards (fig 2835)

In complete dislocation of the talus resulting from supination adduction-inward rotation the talus usually lies *in front of the lateral malleolus* (fig 2834) This is produced in the following way From supination adduction-inward rotation subtalar subluxation of the foot with disruption of the ligaments between the talus and the foot occurs If the force continues to act, subluxation of the talus follows with tear of the talocrural ligaments The foot is then dislocated backwards under the talus and when it recoils to its normal position it catches the talus and carries it forward out of the talocrural joint and it comes to lie in front of the lateral malleolus (figs 2832, 2833, 2833 a, 2836, 2842) In complete dislocation of the talus resulting from pronation-abduction-external rotation the talus usually lies *behind the medial malleolus* This is produced in a similar manner From the pronation abduction-external rotation subtalar dislocation first occurs If the force continues to act there is subluxation of the talus with tear of the ligaments of the talocrural joint The foot then dislocates forward under the talus and when it recoils to its proper position it carries the talus out of the talocrural joint (figs 2851, 2855)

In the last 100 years many articles have been published about the question whether the dislocation first occurs in the talocrural joint or in the talonavicular joint In order to clarify this it must first be basically established that following dislocation of a joint or fracture of a bone through torsion or bending, a dislocation in another joint of the involved extremity or a second fracture can occur only central to the location of the first injury and never peripheral to it because at the portion of the extremity peripheral to the location of the first injury there is no point of fixation for the application of a further force If there is further application of force this can only lead to increase of the displacement at the location of the first injury with tearing of the skin or to a second dislocation or a second fracture or to both located centrally from the first as shown in figure 2832 For these reasons the

to the lateral malleolus (fig 2831) or is so rotated about its vertical axis, that the lateral portion of the trochlea of the talus faces the lateral malleolus (fig 2831 a) In both cases the lateral malleolus remained intact

Sagittal split fractures of the body of the talus also occur in supination external rotation fractures They are produced when the body of the talus is subluxated laterally by half of its width and is then suddenly strongly tilted into pronation with simultaneous longitudinal impaction The lateral edge of the end of the tibia then splits the body of talus longitudinally (fig 2831 b)

Treatment A Steinmann pin is driven through the mid portion of the calcaneus, the leg is placed on the screw traction apparatus (fig 2942 b), and reduction is carried out as in fractures with forward dislocation of the foot (see pp 2012—2014)

Roentgen Check After reduction roentgenograms must be obtained in both planes

Fixation of the Medial Malleolus with Crossed Kirschner Wires When the roentgenograms show good position in both planes, in supination fractures the medial malleolus should be fixed with two crossed Kirschner wires percutaneously as in figures 2734 a and 2828

Application of the Temporary Lower Leg Bed Cast After the placement of the two crossed wires a temporary lower leg cast is applied in the manner described on page 1920 at plantarflexion of 110° to 115° This is immediately split including the last thread

Placement of the Leg on a Braun Splint If the medial malleolus has not been fixed with two crossed Kirschner wires, the fragments will redisplace in the split cast In order to avoid this traction of 5 to 6 kg is applied at the Steinmann pin through the heel, as in open fractures of the tibia (fig 2385) In the case shown in figure 2831 we began with traction of only 3 kg, and minimal redisplacement occured that could no longer be corrected by increasing the traction

Application of a Lower Leg Walking Cast Without Walking Stirrup When the swelling of the joint has completely receded after 8 to 10 days, a lower leg cast without walking stirrup can be applied in those individuals in whom the medial malleolus has been fixed with crossed Kirschner wires They may then walk with crutches without placing any weight on the injured foot

Application of the Walking Stirrup After 8 weeks a walking stirrup is applied for an additional two months The patient may then bear weight on the injured foot

Further Treatment with Unna's paste dressings and exercises is carried out as for malleolar fractures (see p 1930)

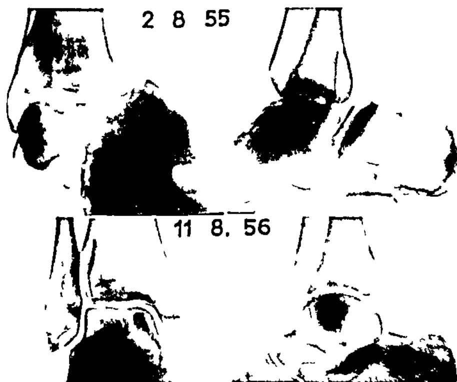
COMPLETE DISLOCATION OF THE TALUS

Definition Complete dislocation of the talus (dislocatio tali totalis) exists when it is displaced from all connections with its four neighboring bones tibia, fibula, calcaneus, and navicular Dislocation then exists in the talocrural, the talocalcaneal and the talonavicular joints



2833

FIG 2833 - Closed complete dislocation of the talus Sustained by a 56 year old railroad crew worker when a heavy rail fell against him There is medial subtalar dislocation of the foot in supination The talus is rotated inwards 90° about its vertical axis so that it can be seen lying transversely in the anterior view and presents end on in the lateral view *Treatment* I was successful in achieving redu tion in the screw traction apparatus with a Steinmann pin throu,h the heel These roentgeno,rams are from a publication by Leitner (see footnot p 2032)



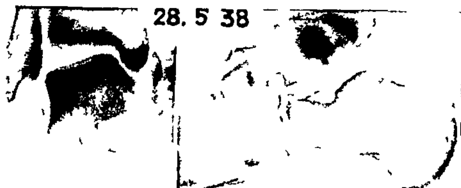
2833 a

FIG 2833 a above —Open complete outward dislocation of the talus Sustained by a 43 year old white farmer s wife in a 3 M fall from a tree The trochlea of the talus lies exposed in the wound similar to that in fig 2834 The foot is dislocated under the talus (subtalar) by its full width medially and in addition upward and backward The talus is rotated about its longitudinal axis 70° in supination in the talocrural joint No rotation has occurred about the vertical axis The shadow of the head of the talus is superimposed on the shadow of the body of the talus The fibular process projects downwards prominently *Treatment* Careful wound excision Reduction by longitudinal traction with subsequent pronation is accomplished without difficulty Suture of the skin Temporary long cast split and windowed Wound treated exposed After 8 weeks lower leg cast for an additional 8 weeks

FIG 2833 a below—Same case after 1 year The joints surrounding the talus all show normal width of the joint spaces Density of the talus normal Talocalcaneal joint immobile Ankle joint 85° to 115° as compared to 65° to 130° on the left These roentgenograms have been taken from a publication by Jorg Bohler [1]

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[1] Bohler Jorg Vollstandige Luxationen des Talus Arch orthopad u Unfallchir 49



2832

FIG 2832 – Medial subtalar dislocation of the foot and anterior subluxation of the foot in supination This represents the medial initial stage of complete dislocation of the talus Reduction under local anesthesia *These roentgenograms have been taken from a publication by* Leitner (see footnote p 2032)

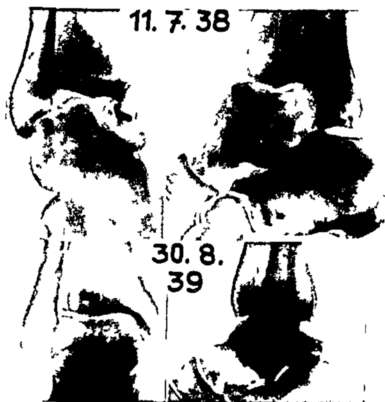
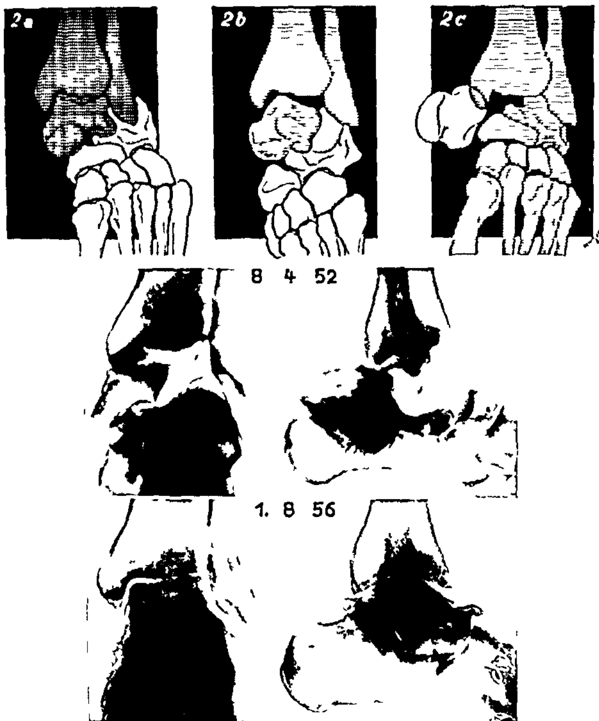


FIG 2832 a above — Beginning of complete outward dislocation of the talus sustained by an 18 year old miller who fell two stories in an elevator when its supporting rope broke The talus is rotated in the ankle joint and in the talocalcaneal joint 40° in supination about its longitudinal axis and seen from laterally is also rotated about its vertical axis There is no medial or lateral subtalar dislocation of the navicular together with the foot by its full width as is usually found The medial malleolus is broken and tipped into valgus A round 10×12 mm shadow can be seen under the tip of the medial malleolus This represents the tibial tubercle of the posterior process of the talus *Treatment* Reduction was relatively easy by forcefully pronating the foot Plaster immobilization

FIG 2832 a below — Same case after 13 months The talus is reduced Its posterior process and the medial malleolus have healed by bony union in good position A shadow extends from the posterior margin of the tibia to the posterior process of the talus It represents the torn and subseqently ossified posterior ligament The joint spaces surrounding the talus are normal in width The talus shows normal density No arthrosis Died 15 years after the injury According to the relatives gait was normal and painless



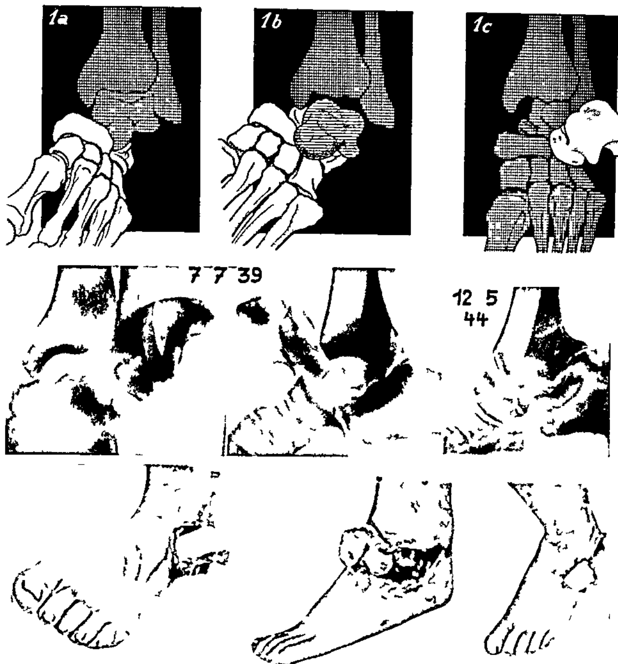
2835

FIG 2835 —Complete inward dislocation of the talus by pronation external rotation in the talocalcaneal joint and supination in the talocrural joint

FIG 2835 above —First an outward and forward subtalar dislocation is produced as in figs 2851 2852 then a partial dislocation in supination in the talocrural joint and finally complete dislocation out of the talocrural talocalcaneal and talonavicular joints These drawings are from a publication by Leitner (see footnote p 2032)

FIG 2835 middle —Closed complete inward and backward dislocation of the talus The talus is rotated 40° in supination about its longitudinal axis 60° plantarward about its transverse axis and 90° inward about its vertical axis The lateral malleolus is fractured at joint level and is in minimal valgus position

FIG 2835 below —Same case after 4 years and 4 months The joint space of the joints surrounding the talus are markedly narrowed Arthrotic spurring can be seen in front and in back on the talus Gait painful and with a limp Arthrodesis planned These roentgenograms are taken from a publication by Jorg Bohler (see footnote p 2029)



2834

Fig 2834 —Development of complete outward dislocation of the talus by supination and inward rotation

Fig 2834 above—Inward and backward subtalar dislocation of the foot is first produced as in figs 2836—2848 then a partial dislocation in supination in the talocrural joint as in figs 2679 2686 e and finally complete dislocation out of the talocrural talocalcaneal and talonavicular joints

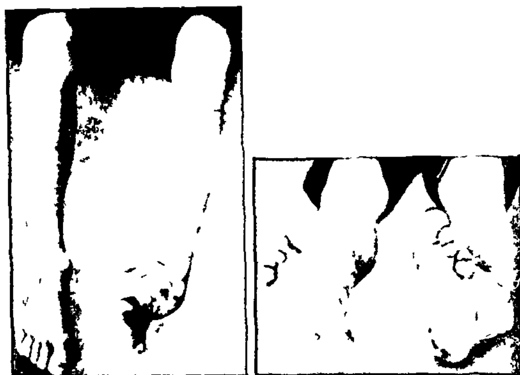
Fig 2834 left middle—The talus is dislocated outward and forward by its full width It is rotated about 30° plantarwards Thus the body of the talus points upwards forwards and laterally while the head of the talus points medially plantarward and backward

Fig 2834 right middle—Same case 5 years after removal of the body of the talus A new irregular joint has formed Only barely per eptible movements possible Gait painful and with a limp

Fig 2834 below—Corresponding photographs The talus remains attached by only remnants of capsule and ligament The drawings roentgenograms and photographs have been taken from two publications by Leitner[1] (see footnote p 2032)

dislocations and the rarest one those directly forward Leitner (see p 2032 footnote) has found that of our 42 fresh cases 36 were inward and backward, 5 outward and forward and only 1 directly backward

Anatomic Changes This dislocation can only occur when all ligaments are completely torn between the talus on the one hand and the navicular and calcaneus on the other hand Of the 36 inward and backward dislocations 19 had only ligamentous tears 6 had an accompanying fracture of the head of



2840 July 1 1929 2841

Fig 2840—Photographs corresponding to figs 2836 2837 The foot is markedly displaced inward and is in maximal supination The head of the talus projects prominently The arch of the foot is normal Transverse fold over the medial malleolus

Fig 2841—Same case seen from the sole The foot is displaced medially under the talus. It is supinated adducted and rotated inward The arch of the foot is normal The lateral malleolus and the head of the talus projects prominently The skin is tightly stretched over the protruding bone bloodless and white

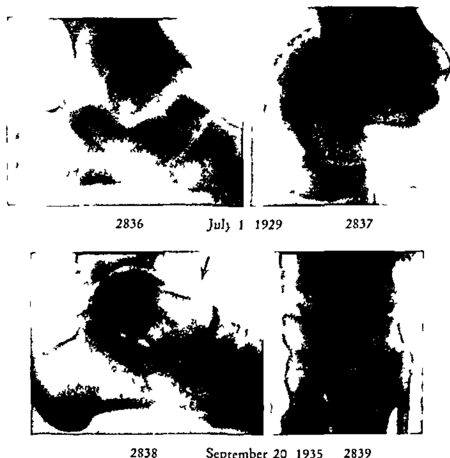
the talus, 10 a fracture of the posterior process of the talus and a fracture of the navicular

In fractures of the *head of the talus* there is a shearing off of a segment of its medial portion by the lateral edge of the navicular In figure 2855 this segment is only impressed by the navicular because the foot was displaced posteriorly to a lesser degree In figure 2855 b this segment is displaced inward and backward with the navicular

In fracture of the *posterior process of the talus* the entire process or only the medial or the lateral tubercle may be sheared off In the outward dislocations the talus is usually in marked plantarflexion, because the tendon of the tibialis posticus which has been displaced from its groove on the posterior part of the medial malleolus to the anterior part of the tibia, passes

119 SUBTALAR DISLOCATION OF THE FOOT

Definition Subtalar dislocation of the foot (luxatio pedis sub talo) exists when the talus retains its normal relationship with the leg while the calcaneus and the navicular together with the remaining bones of the foot distal to the talus are displaced medially, laterally or dorsally (fig 2835 a right) The position of the remaining bones of the foot in relation to each other remains unchanged



2836 July 1 1929 2837

2838 September 20 1935 2839

Fig 2836—Pure inward and backward subtalar dislocation of the foot The talus extends to the first cuneiform

Fig 2837—Same case from in front The head of the talus juts out laterally The navicular together with the foot is dislocated medially as well as backward by almost double the thickness of the navicular The foot is rotated 90° in supination Sustained by a 23 year old laborer who fell 1 M and caught his foot between two beams

Figs 2838 2839—Same case after 6 years Normal position of the bones Dorsally at the head of the talus a small ligamentous ossification Otherwise no abnormal changes Joints freely mobile Ability to walk normal No complaints

Mechanism Subtalar dislocation of the foot results from slipping and falling on level ground, from a fall from a height on the supinated foot, from catching the foot in a crevice with rotation and tipping of the body inward and backward or from a fall on the foot with outward tipping of the body

Displacements Dislocations of the foot inward and backward are the most common (figs 2836—2841), less common are the outward and forward

bances in mobility with pain often follows accompanying fractures of the head of the talus or of the posterior process of the talus

Treatment *Time of Reduction* Reduction should be carried out as soon as possible in order to avoid necrosis from long continued pressure of the talus and subsequent joint infection

Reduction of inward dislocation can usually be carried out under local anesthesia When the original roentgenograms and not sketches are so placed that they can easily be seen during the reduction the patient sits or lies on the table with the knee bent to a right angle and the foot plantarflexed This relieves tension of the Achilles tendon (Vol I/figs 1—6) Then the leg is grasped from in front above the ankle joint with one hand and the heel from behind with the other The heel is then pulled forward as though one were removing the patient's boot When the foot is pulled forward in this manner and the shortening has been corrected, it jumps into place if it is lightly pushed outwards to correct the inward displacement Rotation and angulation are thus also corrected We have usually easily achieved reduction in this manner In simultaneous fractures of the head of the talus or of the posterior process the fragment usually returns to its proper position

If the foot is only pushed laterally without first pulling it forward, reduction cannot be accomplished even with the strongest outward pressure because the medial displacement can only be corrected after the shortening has been corrected

Reduction of outward dislocation cannot as a rule be accomplished by forward and downward traction, i e , in plantar flexion, because the tendon of the tibialis posticus is often interposed between the talus and the dislocated navicular (figs 2855 e, f) The foot can be replaced if the knee and the hip are completely flexed to remove all tension from the Achilles tendon (Vol I/figs 1—6) and then the foot forced into maximal dorsiflexion and pulled forward In this manner the tendon of the tibialis posticus slips forward onto the head of the talus (fig 2855 g) and the foot slips into place if it is pushed inwards and plantarflexed (fig 2855 h) The tendon of the tibialis posticus returns to its groove behind the tibia

First Roentgen Check Roentgenograms must be obtained in the AP and lateral projection in order to determine whether reduction has been complete Sometimes chip fractures can thus be seen that were not visible before reduction

Immobilization When the roentgenograms show good position, a non-padded temporary lower leg bed cast is applied and immediately split through the last thread as for malleolar fractures (see p 1920) In beginning skin necrosis as well as after operation of closed and open dislocations the wound is exposed and treated without dressings

Second Roentgen Check After application of the temporary lower leg bed cast new roentgenograms must be obtained in the AP and lateral projections

Application of the Lower Leg Walking Cast After the swelling has subsided, namely after 8 to 10 days, a lower leg walking cast is applied (see p 1928) If the skin is not in good condition because of necrosis the walking cast

over the trochlea of the talus and the lateral part of the neck of the talus pressing the head of the talus plantarwards (figs 2851, 2855 e, f)

As accompanying injuries fractures of the navicular are sometimes seen with inward dislocations and fractures of the cuboid, calcaneus or lateral malleolus with outward dislocations

All of the intra-articular fractures described usually cause arthroses and impaired movement later

In the inward dislocations a portion of the inferior extensor retinaculum sometimes lodges between the neck of the talus and the navicular This occurs only when the navicular together with the foot is displaced inwards by nearly double the width of the joint surface (fig 2855 c) In the outward displacements the tendon of the tibialis posticus often lies between the neck of the talus and the tibia (figs 2855 e, f)

The skin in inward and backward dislocations is always tightly stretched over the talus and the lateral malleolus and is white and bloodless (figs 2841) After several hours necrosis develops and the skin becomes black Sometimes the tightly stretched skin tears at the lateral side and in the outward dislocations at the medial side so that the talus lies exposed (fig 2855)

Clinical diagnosis is easy, because *in* inward and backward *dislocations* the foot is resiliently fixed in marked supination, adduction and inward rotation A rounded projection can be seen on the lateral side before the development of swelling The skin over the lateral malleolus is stretched to the point of tearing and is white (fig 2841) and after several hours is black The medial malleolus cannot be seen In its place is a transverse skin fold (fig 2840) The sustentaculum tali and the sharply projecting tuberosity of the navicular can be distinctly palpated The foot is displaced backwards *The medial border of the foot appears shortened and the lateral border* appears lengthened

In *outward dislocations* the foot is in pronation, abduction and sometimes external rotation While in inward dislocations there is always marked inward rotation, external rotation is usually not so marked in the outward dislocations and may even be entirely lacking The toes in inward dislocations are usually somewhat dorsiflexed (fig 2841) while in outward and forward dislocations they are often plantarflexed (fig 2855)

Roentgenologic Diagnosis Since the dislocation is present in the talonavicular and talocalcaneal joints and not in the ankle roentgenograms not only of the ankle joint but especially of the talonavicular joint, i e, dorso plantar, should be obtained (fig 2837) Unfortunately they are as a rule omitted Not only gross displacement but also accompanying fractures can be seen on *these*

Possible Complications If reduction is not carried out within a few hours, necrosis of the tightly stretched skin and infection of the joint often develops in the closed dislocations and also in the open dislocations if the wound is not carefully excised and the skin closed (figs 2851, 2855) Arthroses and distur-

culum In the third and fourth cases the navicular was caught on the fracture surface of the head of the talus (fig 2855 a, b) In subsequent similar cases we have been able to disengage the navicular from the fracture surface of the talus without operation by increasing the adduction and inward rotation The foot could then be replaced in the usual manner by pulling it forward as in removing a boot from the foot and then pressing outward It has also been reported that the head of the talus has become caught in the extensors of the toes and has been an obstacle to reduction (fig 2855 d)



2855 July 22 1935

Photographs to figs 2851 2852 Large burst wound extending forward from the medial malleolus The head of the talus lies completely free in the wound The tendon of the flexor hallucis longus lies behind it The foot is displaced laterally by its full width and rotated outward The great toe is maximally flexed because the tendon of the flexor hallucis longus is tensed by the dislocated head of the talus The protrusion of the heel has disappeared and the forefoot is lengthened

Obstacles to Reduction in Outward Dislocation Below the Talus The most common obstacle is interposition of the tendon of the tibialis posticus between the neck of the talus and the navicular (fig 2855 e, f) Overcoming this obstacle by maximal dorsiflexion with the knee and the hip fully flexed is described on page 2037

Treatment of Open Subtalar Dislocations of the Foot The wound must be thoroughly excised according to the rules given in Vol I/pages 149—174 The skin should be sutured after the placement of a drain without burying sutures or ligatures The drain is removed after 24 hours

If infection develops in spite of this especially as a result of skin necrosis the talus should not be removed Under these circumstances ankylosis in the talocrural talocalcaneal and talonavicular joints will develop (figs 2853, 2854) with which the patient will be able to walk satisfactorily At one time I recommended removal of the talus However, we have seen in the follow-up examination that the patients who have had an excision of the talus do not walk nearly as well as those on whom an arthrodesis has been performed (see p 2023 and fig 2830 a)

should not be applied until the involved area is epithelialized or until it is markedly smaller

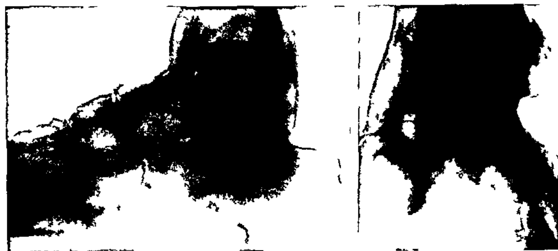
Duration of Immobilization The cast is removed 6 weeks after the injury

Exercise and Further Care is carried out as for malleolar fractures (see p 1928)

Obstacles to Reduction in Inward Dislocation of the Foot Under the Talus Of 36 fresh inward dislocations, 3 could not be reduced by conservative means In the first case interposition of the inferior extensor retinaculum between the neck of the talus and the navicular was found at operation (fig 2855 c) Reduction was easily accomplished after division of the retina



2851 July 2 1935, 2852



2853 June 5 1956 2854

FIG 2851—Pure *open outward* and *forward* subtalar dislocation of the foot The head of the talus juts out inferiorly The navicular is displaced dorsally by double its width and forward The calcaneus together with the foot is displaced so far forward that it no longer projects posteriorly beyond the talus and the malleoli The fore foot is pronated and rotated outward

FIG 2852—Same case from in front The foot is displaced outward by its full width The head of the talus juts downward Sustained by a 35 year old laborer in a 3 M fall from a ladder

FIGS 2853 2854—Same case after 20 years Wound excision and suture was followed by dry necrosis of the wound edges and subsequently by infection of the joint Bony ankylosis of the talocrural the talocalcaneal and the talonavicular joints Moderate bone atrophy No sequestrum

culum In the third and fourth cases the navicular was caught on the fracture surface of the head of the talus (fig 2855 a, b) In subsequent similar cases we have been able to disengage the navicular from the fracture surface of the talus without operation by increasing the adduction and inward rotation The foot could then be replaced in the usual manner by pulling it forward as in removing a boot from the foot and then pressing outward It has also been reported that the head of the talus has become caught in the extensors of the toes and has been an obstacle to reduction (fig 2855 d)



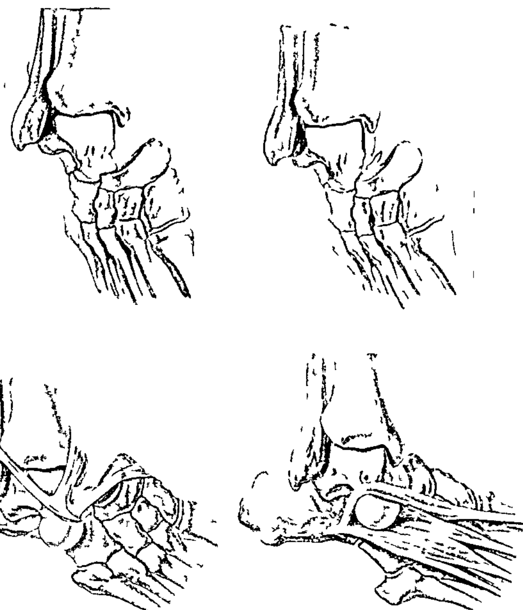
2855 July 22 1935

Photographs to figs 2851 2852 Large burst wound extending forward from the medial malleolus The head of the talus lies completely free in the wound The tendon of the flexor hallucis longus lies behind it The foot is displaced laterally by its full width and rotated outward The great toe is maximally flexed because the tendon of the flexor hallucis longus is tensed by the dislocated head of the talus The protrusion of the heel has disappeared and the forefoot is lengthened

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2855 a—d

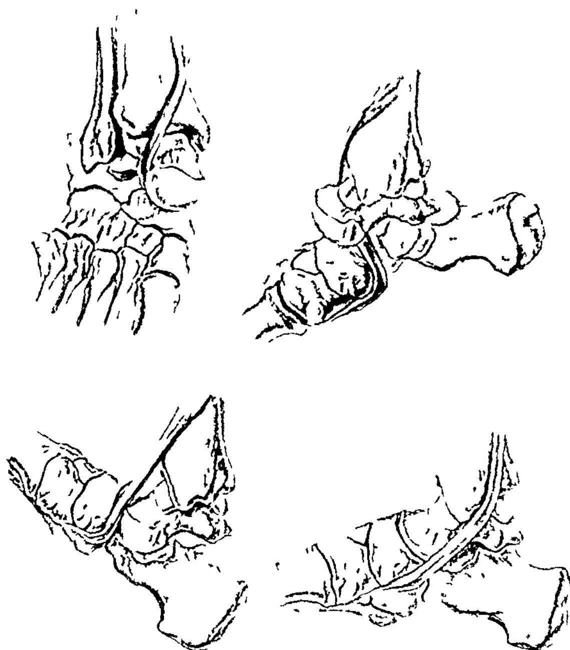
Obstacles to reduction in medial subtalar dislocation of the foot

Fig 2855 a upper left —The medial part of the head of the talus is notched by pressure of the lateral edge of the navicular which is caught in the notch The bones can be disengaged by adduction and inward rotation of the forefoot followed by pulling forward at the heel as in pulling off a boot Then reduction can usually be readily accomplished by abduction and external rotation

Fig 2855 b upper right —The medial part of the head of the talus is sheared off by the lateral edge of the navicular The bones can be disengaged in the same manner as in fig 2855 a

Fig 2855 c lower left —In marked inward and backward subtalar displacement of the foot the inferior extensor retinaculum can be interposed between the neck of the talus and the dislocated foot This obstacle to reduction can sometimes be overcome by increasing the adduction and inward rotation with simultaneous pulling forward of the foot as in removing a boot and subsequent dorsiflexion of the foot If this is not successful the retinaculum must be operatively divided

Fig 2855 d lower right —Incarceration of the head of the talus between the short extensors of the toes When this rare obstacle to reduction cannot be overcome by pulling the foot forward as in removing a boot reduction must be carried out operatively This can easily be accomplished



2855 e—h

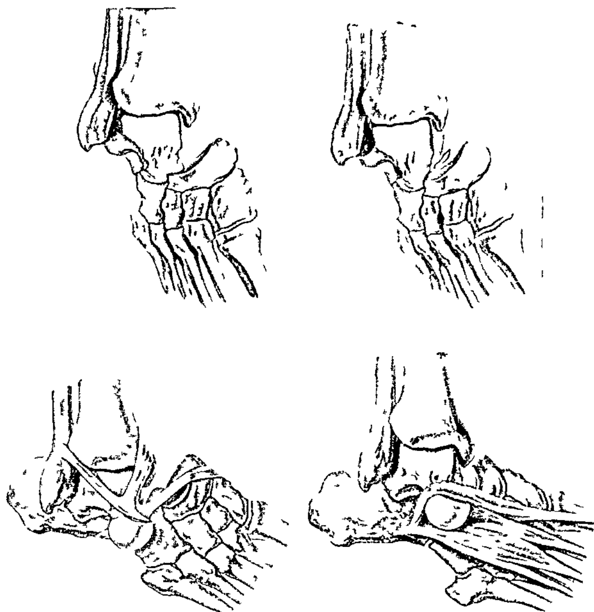
Fig 2855 e—h —Interposition of the tendon of the tibialis posticus muscle as obstacle to reduction in outward subtalar dislocation of the foot

Figs 2855 e f above —The tendon of the tibialis posticus muscle is torn out of its groove on the posterior surface of the tibia by forward and lateral displacement of the foot and slips over the head of the talus to the lateral side of the neck of the talus and thus obstructs reduction

Fig 2855 g lower left —This obstacle to reduction can be overcome by forcefully pulling the foot forward as in removing a boot with the foot in marked dorsiflexion As a result the tendon glides forward onto the head of the talus By subsequent adduction inward rotation and plantar flexion the foot slips into its proper position

Fig 2855 h lower right —The foot is reduced The tendon again rests in its proper place

Figs 2855 a—h are taken from a publication by Leitner[1] (see p 2032 below)



2855 a—d

Obstacles to reduction in medial subtalar dislocation of the foot

Fig 2855 a upper left —The medial part of the head of the talus is notched by pressure of the lateral edge of the navicular which is caught in the notch The bones can be disengaged by adduction and inward rotation of the forefoot followed by pulling forward at the heel as in pulling off a boot Then reduction can usually be readily accomplished by abduction and external rotation

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Fig 2855 d lower right —Incarceration of the head of the talus between the short extensors of the toes When this rare obstacle to reduction cannot be overcome by pulling the foot forward as in removing a boot reduction must be carried out operatively This can easily be accomplished

13 In open dislocations and infections have I avoided removing the talus, because one is better able to walk with ankylosis of all of the joints of the talus than without the talus?
14 After uncomplicated dislocations have I removed the cast after 6 weeks?
15 In the presence of infection have I continued plaster immobilization for 6 to 8 months until ankylosis has developed?

Results Following Treatment of 42 Fresh Subtalar Dislocations of the Foot

Leitner (see p 2032 footnote) has carried out complete follow-up examinations on the 42 patients with fresh subtalar dislocations of the foot treated by us between the years 1925 and the end of 1950 and has compared these with the cases described in the world literature In all he was able to find only 241 published cases of fresh dislocations, mainly single cases Astrup alone described 18 cases from 4 Danish hospitals and Pampero 6 of his own Thus we have by far the largest number of reexamined cases Until the end of 1955 we have treated an additional 29 cases They have however not yet been reexamined

Of the 42 cases, 36 dislocations were medial, 5 lateral and one posterior The relative numbers of closed to open show the following figures

	closed	open	sum
medial	33	3	36
lateral	4	1	5
dorsal	1	0	1
	38	4	42

Of the 36 medial dislocations he was able personally to reexamine 32, of the 5 lateral dislocations 4, and the 1 backward dislocation, namely, 37 of the 42 cases He presented complete clinical and roentgenologic findings

Deaths One patient with an open dislocation died from gas gangrene (1941)

Infections occurred twice, in both cases as a result of skin necrosis The first case was an open lateral dislocation (figs 2851—2855) and the second a closed medial dislocation which had to be reduced operatively because of interposition of the inferior extensor retinaculum

He divided the 36 *medial cases* into 4 groups according to the results of treatment

A Medial group without accompanying injuries of the talus (pure dislocation) 19 cases
B Medial group with accompanying fracture of the head of the talus 6 cases
C Medial group with accompanying fracture of the posterior process of the talus 10 cases
D Medial group with accompanying fracture of the navicular 1 case

Of the 19 cases of *Group A* he was able to reexamine 17 One patient was a war casualty and another moved to a foreign country Of the 17 cases that were reexamined 16 had been reduced nonoperatively and one operatively 11 patients had no complaints whatever with free active mobility of all joints

Immobilization following wound excision and reduction is done in a similar manner as for malleolar fractures (see p 1920) The wound must be exposed for treatment without dressings The lower leg walking cast may not be applied until the wound is epithelialized or is markedly reduced in size If infection develops, the cast must be worn until ankylosis is complete That is usually in 6—8 months

Questions We Should Ask Ourselves in Order to Avoid Failures in the Treatment of Subtalar Dislocations of the Foot

In addition to those questions outlined on pp 1933—1940 for malleolar fractures the following should be considered

1 Have I noted the position of the foot during the examination (supination adduction inward rotation or pronation abduction-external rotation)?
2 In inward dislocations have I observed the skin over talus and the lateral malleolus to see if it is tightly stretched and white or in early necrosis black?
3 Have I observed whether in inward dislocations the great toe is dorsiflexed or in outward dislocations it is plantar flexed?
4 Have I obtained dorsoplantar and lateral roentgenograms of the talo navicular joint since the dislocation occurs in the talonavicular and talo-calcaneal joints and not in the ankle joint?
5 Have I looked for fractures of the head of the talus, the posterior or lateral process or of the surrounding bones (navicular, cuboid, calcaneus or lateral malleolus)?
6 In outward dislocations have I observed whether the talus is strongly plantar flexed (figs 2851, 2852)?
7 Have I so placed the roentgenograms that they can easily be seen during reduction?
8 In inward dislocations, after local anesthesia have I positioned the knee at a right angle and strongly plantarflexed the foot at the ankle in order to remove tension from the Achilles tendon (Vol I/figs 1—6 and fig 2644)?
9 Have I pulled the foot forward as in removing a boot in order to correct the shortening and then corrected the inward dislocation by slight outward pressure?
10 In inward dislocations with fracture of the head of the talus on which the navicular is caught (fig 2855 a) have I disengaged the bones by increasing adduction and inversion?
11 In outward dislocations have I maximally dorsiflexed the foot with the knee and hip fully flexed, in order to free the interposed tendon of the tibialis posticus and then pulled the foot forwards and thereupon pushed it inwards (figs 2855 e—h)?
12 After the application of the temporary lower leg cast have I left exposed wounds or necroses for treatment without dressings?

freely movable There was pain and swelling The patient walked with a slight limp

Of the 5 *lateral dislocation* 4 could be reexamined One patient moved to another country 4 of the 5 dislocations were closed and one open All worked in the same occupation prior to injury

In the first case ankylosis of the three joints of the talus in mid position (figs 2851—2855) followed an infection resulting from skin necrosis The toes are in mid position and cannot be actively moved but are passively limited only at the extreme ranges of motion The patient walks with a slight limp, because of the stiffness of the foot but has no pain Skin color is normal Has symptoms from an ulcer in the scar

The second patient moved to another country and could not be reexamined

The third patient had a partial dislocation in the ankle joint, a fracture of the posterior process and a fracture of the outer malleolus in addition to the subtalar dislocation In this case movement at the ankle joint was limited by 20° while the talocalcaneal joint was immobile He complained of severe pain especially in the morning and developed swelling especially in the evening Gait without a cane was painful and limping

In the fourth patient there were no associated injuries All joints were actively freely movable Skin color was normal There was no swelling and no muscle atrophy Gait was normal

The fifth patient had an associated fracture of the head of the talus and of the posterior process The ankle joint was limited by 10° and the talocalcaneal joint by three fourths In spite of this the patient had no complaints There was no swelling and no muscle atrophy Skin color and gait were normal

The first case with ankylosis as well as the one on p 2044 shows that in these patients walking is painless if ankylosis occurs in mid-position, and that therefore an arthrodesis should be carried out in the presence of marked symptoms due to arthroses

The only patient with a *posterior dislocation* had limitation of motion of the ankle of 30° The talocalcaneal joint was immobile He had increasing pain and tendency to swelling The roentgenogram showed an arthrosis of the talonavicular and the talocalcaneal joints

120 FRACTURE OF THE CALCANEUS

Classification of Fractures of the Calcaneus

In 1930 I divided fractures of the calcaneus into eight groups according to the mechanism of fracture, treatment and result, namely, into fractures of the processes of the calcaneus and fractures of the body of the calcaneus Fractures of the tuber are extra-articular (groups 1 a, 1 b, 1 c and 2) and those in the remainder intra-articular (groups 3 a and 3 b) Fractures behind the joint surfaces of the calcaneus are extra-articular (group 4) and all fractures

4 patients had free active mobility of all joints with occasional pain and discomfort on change of weather These patients were industrially insured Two patients had limitation of motion of the ankle joint up to 30° and of the talocalcaneal joint of one half One of these sustained a second injury two months after the first in which he sustained a fracture in the same leg of the lateral malleolus with lateral subluxation In none of the 17 cases was there swelling or muscle atrophy Skin color was normal in all All were in the same type of work that they had been before injury

Of the 6 cases of *Group B* with simultaneous fracture of the neck of the talus 4 were reexamined Two were reduced operatively because the navicular was caught on the fracture surface (figs 2855 a, b) One patient died from gas gangrene, and one moved to another country In all 4 patients motion in the ankle joint was limited (in one by 10°, in one by 15° and in two by 20°) Mobility in the talocalcaneal joint was also limited, twice by one third, once by two thirds and once it was immobile Active motion in the toes was normal All complained of symptoms (pain, tendency to swelling, and sensitivity to weather changes) In two cases swelling was present at the time of reexamination Skin color was normal in all 4 cases Gait in one case was with a slight limp while in the other 3 it was normal All 4 continued in the same type of work as before the injury

Of the 10 cases of *Group* C with simultaneous fracture of the posterior process of the talus all were reexamined In 9 reduction was nonoperative while in one operative reduction was necessary Mobility in the *ankle joint* was normal in only one case In the others it was limited, once by 5°, five times by 10°, once by 15° and once by 35° In one, ankylosis followed infection as a result of skin necrosis Motion in the *talocalcaneal joint* was limited in all 10 cases 4 times by one half, once by three fourths once almost completely and 3 times completely immobile, among these the case with ankylosis mentioned under the ankle joint In 8 cases mobility of the toes was normal In 1 case active motion was limited by one third while passive motion was normal and in one case, namely in the case with ankylosis after infection the toes were in mid position and could not be actively moved but were passively limited only at the extreme ranges of motion With the exception of the patient with the ankylosis, all complained of pain, sensitivity to changes in the weather and tendency to swelling Skin color was normal in all patients Swelling a sign of circulatory disturbance, was present in 3 patients at the time of reexamination. Gait was normal in 7 patients In 2 there was a suggestion of a limp and once in the patient with the ankylosis, there was a slight limp with inelasticity of the foot

The fact that the patient with ankylosis of all 3 joints of the talus is the only one in this group who has no pain after 16 years shows that in the presence of significant pain an arthrodesis should be carried out more often and proves that in the presence of infection it is better not to remove the talus

The one patient of *Group D* with simultaneous fracture of the navicular was reexamined 1½ years after the injury The ankle joint was freely moveable while the talocalcaneal joint was almost completely immobile The toes were

freely movable There was pain and swelling The patient walked with a slight limp

Of the 5 *lateral dislocation* 4 could be reexamined One patient moved to another country 4 of the 5 dislocations were closed and one open All worked in the same occupation prior to injury

In the first case ankylosis of the three joints of the talus in mid position (figs 2851—2855) followed an infection resulting from skin necrosis The toes are in mid position and cannot be actively moved but are passively limited only at the extreme ranges of motion The patient walks with slight limp, because of the stiffness of the foot but has no pain Skin color is normal Has symptoms from an ulcer in the scar

The second patient moved to another country and could not be reexamined

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through the body are intra-articular (groups 5—8) In group 7 the talo navicular joint is involved, and in group 8 the calcaneo-cuboid joint

Jimeno Vidal reviewed our 182 fresh cases from the seven years 1926 to 1932 from the standpoint of this classification and determined the frequency of the different groups Gollasch has re-examined our fresh fractures of the calcaneus from the years 1926—1935 His figures were similar to those of Jimeno Vidal and are shown in parentheses The 1852 cases from the years 1926—1956 are now being reviewed

Group 1 a Fractures of the posterior upper end of the tuber calcanei proximal to the insertion of the Achilles tendon, so called duck-bill fractures (figs 2855 m, 2889, 2912, 2913, 2913 a, 2913 b) Incidence 1 = 0 5% (1 = 0 4%)

Group 1 b Fractures of the posterior end of the tuber that begin at the lower end of the insertion of the Achilles tendon and under the transverse crest of the tuber with duck bill form (fig 2855/1, n—qu)

Group 1 c Fractures at the posterior upper end of the tuber that begin below the transverse crest of the tuber in which the fragment does not tip up as in groups 1 a and 1 b, but is displaced proximally and parallel to the fracture surface (figs 2855 r s)

Group 2 Fractures of the medial process of the tuber with and without displacement (figs 2855 t—u, 2891 2892, 2914, 2963) Incidence 23 = 13% (28 = 15 4%)

Group 3 a Isolated fractures of the sustentaculum tali (fig 2890) Incidence 8 = 4% (10 = 4%)

Group 3 b Fractures at the anterior process of the calcaneus, not yet counted (figs 2884 a 2884 b)

Group 4 Fractures of the tuber calcanei (figs 2855 v—x 2921 a, b, 2947 to 2950) and of the body of the calcaneus without displacement of the joint surfaces adjacent to the talus (figs 2893, 2894) Incidence 46 = 25% (67 = 27 10%)

Group 5 Fractures of the body of the calcaneus with partial or complete dislocation with respect to the talus of the lateral portion of the posterior joint surface which is broken off from the tuber behind the joint surface (figs 2922—2923) Incidence 55 = 30% (82 = 33 2%)

Group 6 Fractures of the body of the calcaneus with dislocation in relation to the talus of the entire posterior joint surface which remains attached to the tuber calcanei In these a broad gap can be seen between the posterior parts of the talus and the calcaneus (figs 2897 2932 2933) Incidence 5 = 3% (8 = 3 2%)

Group 7 Fractures of the body of the calcaneus with dislocation with respect to the talus of the lateral part of the posterior joint surface and with accompanying patial dislocation between the head of the talus and the navicular (fig 2901) and between the anterior part of the calcaneus and the cuboid (partial dislocation in Chopart s joint) Sometimes the posterior process of the talus is also broken off Incidence 21 = 12% (13 = 6 10%)

Group 6 Fractures of the body of the calcaneus with comminution of the anterior process and dislocation of the anterior process with respect to the cuboid (figs 2901, 2903) Incidence 20 = 11% (26 = 10 6%)

In addition to these are three pathological avulsion fractures of the entire tuber calcanei two with tabes (figs 2905, 2906) and one in poliomyelitis Incidence 3 = 1 5%

Mechanism of Fractures of the Calcaneus

Anatomy of the Dorsal Surface of the Tuber Calcanei and the Insertion of the Achilles Tendon The dorsal surface of the tuber calcanei is divided into two parts by the transverse crest of the tuber calcanei (H R Schonbauer) Sometimes the upper (fig 2855 i) is the larger and sometimes the lower (fig 2855 k) The Achilles tendon spreads out to insert into the calcaneus above and below this transverse crest The insertion of the tendon extends farther proximally on the medial side The cranial surface of the tuber is smooth and covered with cartilage Between the cartilaginous surface and the tendon is a bursa and a fat pad When the transverse crest is situated high, this bursa is small (fig 2855 i) and when it is situated low the bursa is larger (fig 2855 k), as can be well seen in the dissections by Korn[1]

Mechanism in Fractures of the Calcaneus of Group 1 a (see p 2046) Fractures in the cranial dorsal portion of the tuber are usually considered as avulsion fractures presumably resulting from the pull of the Achilles tendon This explanation cannot be correct for the fractures of group 1 a, since they are located proximal to the insertion of the Achilles tendon (fig 2855 m) As a matter of fact, we have seen that in most fractures in this area a direct force struck the calcaneus from behind (fig 2889) or from the side A transverse crack is thus produced in the cortical bone as in the experiment of Korn who marked the surface of the cortical bone with a chisel He was then able to produce a typical duck-bill fracture by pull on the Achilles tendon (fig 2855 l) This was not possible when the bone was uninjured When the fracture lies proximal to the insertion of the Achilles tendon (figs 2855 l, k), the fragment is tipped up by pressure of the Achilles tendon during dorsi flexion at the ankle (figs 2855 m, 2889, 2913) Sometimes it is tilted into an almost vertical position and the ventral tip then slips dorsally to the middle of the fracture surface and is there tightly impacted (fig 2913 a) These rare fractures usually occur only in persons over 50 A certain degree of osteoporosis seems to be prerequisite to the development of this fracture in addition to the unique mechanism of injury

Mechanism of Fractures of the Calcaneus of Group 1 b (see p 2046) These are produced in the same way and have the same age requirement as those of groups 1 a The only difference is that the crack in the bone is produced through the transverse crest of the tuber (fig 2855 o) or caudal to it (fig 2855 n) and that the fragment is then torn upward by a sudden pull of the Achilles tendon Its caudal edge can then be seen (fig 2855 p) and felt

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[1] Korn Der Bruch durch das hintere obere Drittel des Fersenbeines Arch orthop u Unfall Chir *41* 789—804 1942

(fig 2855 qu) The skin protrudes over the edge of the fragment, is white and ischemic and is pulled inward below it (fig 2855 o) When the patient is first seen late, as in figure 2855 o, skin necrosis develops over the sharp fragment In group 1 a on the other hand there is no danger to the skin because the Achilles tendon lies between it and the fragment

Fractures of the calcaneus, group 6 in which the fracture through the dorsum of the tuber gapes more or less should not be mistaken for "duck bill fractures of groups 1 a and b, as they are joint fractures in which the lateral part of the posterior joint surface remains united to the cranial portion of the tuber calcanei

Mechanism of Fracture of the Calcaneus Group 1 c (see p 2046) These are *produced in the same manner and occur in the same age group as fractures* of group 1 a They differ however in that the fragment is not tilted up to produce the duck bill' but rather is pulled cranial for a variable distance by the tension of the Achilles tendon so that the fracture surfaces remain parallel (figs 2855 r, s) Sometimes, the fragment is broken into several pieces by the direct action of the force as in our case which was described by Schonbauer [1]

In one case we found mucoid degeneration of the insertion of the tendon at histological examination similar to those found in tears of the Achilles tendon In both of these injuries tissues are present that are no longer normal The age groups involved are, however, different, since tears of the Achilles tendon usually occur between the ages of 30 to 50, while fractures of the posterior upper third of the tuber calcanei usually occur between the ages of 50—70

Mooney has described epiphysiolysis at the insertion of the Achilles tendon with marked cranial displacement which occurred in a 13 year old girl from a sudden turn at play The fragment was displaced parallel upward in a similar manner to that in fig 2855 s and was not tipped up as in figs 2855 l—o

Mechanism of Fractures of the Calcaneus Group 2 (see p 2046) These occur as a result of a fall on the heel when the foot is pronated and dorsiflexed The processus medialis of the tuber calcanei is thus sheared off and sometimes cranially displaced Displacements toward the sole (fig 2914) and toward the toes (fig 2963) are very rare The patients from this group are younger than those with fractures of the body of the calcaneus Jimeno Vidal [1] found an average age of 33 5 years in 66 cases while fractures of the body of the calcaneus occurred at an average age of 42 He presents excellent sketches showing the mechanism of these fractures (figs 2855 t, u) We have seen avulsion of this bone with displacement towards the toes from the pull of the plantar muscles in a case of a fracture dislocation in Chopart s joint (fig 2963)

Mechanism of Fractures of the Sustentaculum Tali (group 3 a see p 2046) These occur from falls on the supinated foot (fig 2890)

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1 Schonbauer H R Abrisse der Achillessehne von ihrem Ansatz Zentralbl Chir *77* 270—271 1952

Mooney Avulsion of the Epiphyses of the Achilles tendon J Bone Surg *17* 1057 to 1058 1935

3 Vidal Jimeno Isolierte Abscherungsbruche des Tuber calcanei Der Chirurg *13* 47—51 1941

Mechanism of Fractures of the Anterior Process of the Calcaneus (group 3 b, p 2046) *Larger fragments are sheared off with the foot sharply dorsiflexed* In this way the bill shaped process is broken off from the dorsal edge of the anterior process (fig 2854 b) In recent years these have often occurred in falls on skis with diagonal bindings that bind the foot to the ski and do not allow the heel to come up from the ski

Fractures in which smaller fragments are broken off occur at plantarflexion by sudden adduction of the forefoot in Chopart s joint A bone fragment is thus avulsed from the dorsal edge of the anterior process by the pull of the ligamentum bifurcatum or at the insertion of the short extensors of the toes This is located more medially or laterally depending on the shape of the calcaneus (fig 2854 a)

Mechanism of Shearing and Bending Fractures of the Tuber Calcanei (group 4 see p 2046) Sometimes only the posterior edge is sheared off *sometimes half and sometimes the entire tuber* The shearing off of the posterior edge results when the patient falls so that his heel strikes an object such as the rung of a ladder which is lying on the ground a rock, or a low step and the foot is forced into plantarflexion Shearing off of the posterior portion of the tuber calcanei thus results while the lateral process remains united with the main fragment Jimeno Vidal[1] has depicted this mechanism in a lucid sketch (fig 2855 v) The sheared off posterior fragment often breaks transversely in two (fig 2855 w) It sometimes happens that the medial process does not break off but remains united with the main fragment as in figures 2921 a, b In tabes the medial process and the lateral process break off (fig 2905)

Fractures in which the entire tuber calcanei is broken off with the fracture in a frontal plane just behind the joint surface usually are produced by bending The large fragment is often displaced cranially (fig 2947) and not infrequently shears off the posterior process of the talus We also classify intra-articular fractures without displacement with group 4 (fig 2843)

Shearing fractures in tabes can occur in pathologically altered bone even from a forceful step in a manner similar to the shearing fractures of normal bone that result from a fall on the posterior part of the heel (fig 2855 v) The large sheared off fragment breaks transversely in two at the insertion of the Achilles tendon, and the cranial fragment is pulled upwards by it (fig 2905) At the same time the medial process and the lateral process are broken off and have separated from each other (fig 2906)

Mechanism of Fractures of Groups 5 to 8 (see pp 2046, 2047) These always involve intra-articular fracture of the body of the calcaneus They usually result from a vertical fall with the knee extended and often the foot in pronation They have also often been produced in explosions on ships and land mines I have seen 18 calcaneus fractures in a single day following an attack over heavily mined terrain There have been scattered reports of calcaneus fractures from explosions of pipes and from recoil of the starter of

[1] Vidal Jimeno Isolierte Abscherungsbrüche des Tuber calcanei Der Chirurg *13* 47—51 1941



2855 i 2855 j 2855 k

Fig 2855 i —Insertion of the Achilles tendon on the tuber calcanei in the presence of a high transverse crest — betw en two needles The bursa in front of the tendon is small

Fig 2855 j Insertion of the Achilles tendon on the tuber calcanei in the presence of a low transverse crest — between two needles The bursa in front of the tendon is large

Fig 2855 k —After notching the tuber calcanei with a chisel just below the ins rtion of th Achilles tendon a typical duck bill fracture occurred when traction was exerted on the tendon These roentgenograms have been taken from a publication of my former assistant Korn (see footnote p 2150)



2855 m 2855 n

Fig 2855 m Duck bill fracture above the transverse crest of the tuber calcanei and therefore above the insertion of the Achilles tendon (group 1 a)

Fig 2855 n —Duck bill fracture below the transverse crest of the tuber calcanei The fragment is pulled up by the Achilles tendon (group 1 b)



2855 o 2855 p 2855 q

Fig 2855 o —Duck bill fracture in which the skin has been pulled sharply inward Along with the wedge a lamella of bone was avulsed below the transverse cres of the tuber calcan i similar to that in fig 2913 a and was bent upward Condition on admission 4 days after injury The skin showed beginning necrosis (group 1 b)

Fig 2855 p —The skin is pushed outward by the fragment It is white and bloodless (group 1 b)

Fig 2855 q – One can insert a finger in the hollow below the fragment as evidence that the Achilles tendon is no longer attached to the tuber calcanei

Figs 2855 p and q are taken from a publication by S ruppler[1]

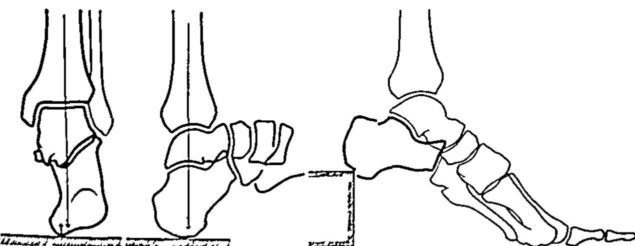
[1] Struppler Rißbruch am Fersenbeinhocker Arch orthop u Unfallchir 658 1959




2855 r 2855

Fig 2855 r—Avulsion fracture of the tuber calcanei at the level of the transverse crest The fragment is displaced upward by its full height but is not tipped (group 1 c)

Fig 2855 s—Avulsion fracture from the lower edge of the tuber calcanei The fragment is displaced upward by more than its entire height but is not tipped up (group 1 c)



2855 t 2855 u 2855 v

Fig 2855 t and u Mechanism of a shearing fracture of the medial process of the tuber calcanei from falling on the pronated dorsiflexed foot From Jimeno Vidal (group 2)

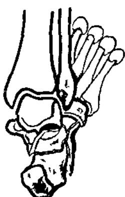
Fig 2855 v—Mechanism of a shearing fracture of the entire dorsal margin of the tuber calcanei by landing on a hard object with the posterior portion of the heel and from the resulting plantarflexion From Jimeno Vidal (group 4)

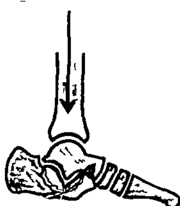



2855 w 2855 x

Fig 2855 w—Shearing fracture of the posterior margin of the tuber calcanei The fragment is itself broken below the transverse crest The cranial portion is displaced upwards (group 4)

Fig 2855 x—Shearing fracture of the posterior margin of the tuber calcanei Not only the posterior margin but also the upper margin is sheared off as in the duck bill fractures (group 4)



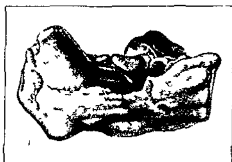


2856 Sketched on December 12 1928 2857

FIG 2856—View of the fractured calcaneus from behind The lateral wall is broken off and medially the sustentaculum tali with a wedge shaped posterior process that includes the medial portion of the posterior joint surface of the calcaneus The intermediate fragment which includes the larger lateral portion of the posterio joint surface of the calcaneus is completely separated anteriorly and posteriorly from the body of the calcaneus The calcaneus is broadened (group 5)

FIG 2857—The calcaneus which is fixed on the ground is comminuted by the wedge shaped lateral portion of the talus which transmits the force of the falling body The tuber calcanei is forced upward so that a cranially open angle results The posterior joint surface of the calcaneus is driven downward and subluxated in relation to the talus (group 5)





2858 Photographed September 11 1929 2859

FIG 2858—Fracture of the calcaneus from a drawing by Malgaigne in 1848 seen from above The typical sagittal and horizontal fracture lines are well shown The lateral wall is pushed forward Medially the sustentaculum tali is continuous with a large wedge shaped fragment which includes the medial portion of the posterior joint surface *The lateral portion of the posterior joint surface of the calcanus is forced downward* There are two longitudinal fracture lines through the anterior portion of the calcaneus (groups 6 and 7)

FIG 2859 Drawing of another fracture of the calcaneus by Malgaigne seen from the side The lateral wall is forced forward The lateral portion of the posterior joint surface has been forced downward and the posterior portion of the tuber calcanei has been bent posteriorly and upward The sustentaculum *tali is in its normal position The tuber joint angle is negative* (group 6)



2860 November 15 1928 2861

Fig 2860 Plantar dorsal roentgenogram of a fracture of the calcaneus taken obliquely from the sole to the Achilles tendon as in fig 2907 The lateral wall is broken off and forced outward and forward Medially the sustentaculum tali with a large wedge shaped portion which includes the medial portion of the posterior joint surface is in its normal position The lateral portion of the posterior joint surface cannot be seen in the roentgenogram because it has been forced downward (Compare with the lateral view) The tuber calcanei is adducted

Fig 2861 —Lateral view of same case The cranial portion of the tuber calcanei is displaced backward and upward and has a horizontal fracture The posterior joint surface of the calcaneus has been driven so far downward that it reaches the sole surface of the calcaneus with its anterior edge The subluxated joint surface appears as a curved line The anterior portion of the joint surface is intact and the joint between the talus and the navicular (talo navicular joint) is not destroyed (group 6) The tuber joint angle is 0°



2862 September 21 1929 2863

Fig 2862 —Same case after 10 months The shortening and the broadening of the calcaneus and the adduction with the medially open joint have disappeared The fragments have healed with good callus

Fig 2863 —Same case lateral view Tuber joint angle 18° The dislocated lateral portion of the posterior joint surface is now in proper position The joint is somewhat narrowed Pronation and supination limited by one third Gait painless and durable without a limp Reduced in the screw traction apparatus Then 6 weeks continuous traction in a cast followed by 6 weeks immobilization in a walking cast

a motorcycle I have seen this fracture only once as a skiing injury There are also cases in which the calcaneus was fractured when a heavy object fell on the thigh while the knee was bent (Jimeno Vidal) These fractures can even occur when the subject is sitting when a mine explodes under a tank or other vehicle



2864—2871 November 6 1929

Left foot with fractured calcaneus with a normal right foot for comparison from medial and from lateral Above with the talus and below after its removal The tuber joint angle is negative the longitudinal arch has disappeared

In a vertical fall the momentum of the body is transmitted by the tibia to the talus This is forced against the calcaneus with its wedge sharped fibular portion In the fall the calcaneus touches the ground first and is already fixed when the force of the fall begins to act (fig 2857) At the same time the tuber calcanei is bent cranially Thus bending and shearing of the bone is produced in addition to compression By the action of a greater force the calcaneus is

comminuted (figs 2856—2875) If the force is especially great, the tuber calcanei is sheared off (figs 2951, 2955) or the talus is also fractured (fig 2829) The types of fracture are manifold and depend on the magnitude of the force producing them (see p 2064)

The calcaneus can also be fractured when a heavy object falls against its side or when it is compressed between two objects The fracture lines are then atypical The damage to the skin is often predominant in these direct types of fractures

Associated injuries are relatively common Gollasch found them 34 times (15%) in our 250 patients Associated vertebra fractures are among the most



November 6 1929

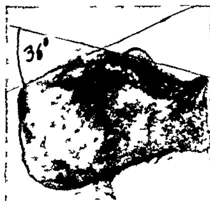
Figs 2872—2875 – Fracture of the calcaneus left and for comparison a normal calcaneus right The fractured calcaneus is markedly broadened and shortened The lateral wall projects far beyond the talus laterally

important of these The most severe calcaneus fractures are often accompanied by fractures of the leg (tibia and fibula) of the same side In marine warfare Magnus often found a fracture of the medial tibial condyle accompanying the closed injuries of the calcaneus, while the open injuries were often accompanied by tibiofibular shaft fractures The fracture of the medial tibial condyle apparently is related to the spraddle-legged stance adopted by seafaring men Otherwise this fracture is not associated with fractures of the calcaneus

Fracture Types and Displacement of Fragments

The fracture forms and displacement of the fragments depend on the distance of the fall and the weight of the subject (Force — Mass × Velocity = $\frac{mv}{2}$) and in marine and land warfare injuries on the force of the explosion and the distance from the center of the explosion on the position of the foot in relation to the leg (pronation, supination plantar- or dorsiflexion), on the form of the foot (normal, flat-foot or pes cavus), because the direction of





2876 Septembur 11 1929 2877







2878 2879 2880

October 20 1928

Fig 2876—Tuber joint angle of 36° on the skeleton of a normal foot

Fig 2877—Tuber joint angle of an isolated calcaneus

Fig 2778—Skeleton of the foot seen from behind from a 45° angle The tuberosity of the fifth metatarsus can be seen below the lateral malleolus The sustentaculum tali with its joint surface for the talus can be seen medially The joint space between the posterior joint surface of the talus and the calcaneus can be seen laterally In this projection this joint is located 3 to 4 mm behind that of the sustentaculum The anterior half of the calcaneus cannot be seen

Fig 2879—Dorsoplantar roentgenogram of a normal calcaneus The sustentaculum tali with its joint surface opposite the talus can be seen medially The joint space between the posterior joint surfaces of the talus and the calcaneus can be seen laterally The exposure was made with the patient standing The film cassette was under the sole and the central ray was directed at the calcaneus at an angle of 45° One can obtain the same picture with the patient lying down and the central ray directed at the sole at an angle of 45° with the foot dorsiflexed and the film cassette under the heel and the leg Compare with fig 2907

Fig 2880—Isolated calcaneus at an angle of 45° seen from behind The sustentaculum tali projects medially as a broad ridge Very little can be seen of the anterior half of the calcaneus



Fig 2881 Normal tuber joint angle of 35° in an uninjured calcaneus The longitudinal axis of the talus is oblique

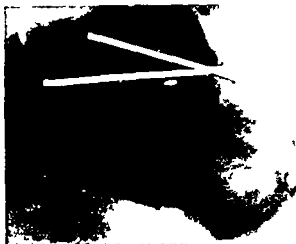


Fig 2882 July 8 1929—Tuber joint angle of 20° in a relatively mild fracture of the calcaneus The longitudinal axis of the talus approaches the horizontal (group 4)

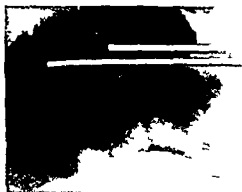


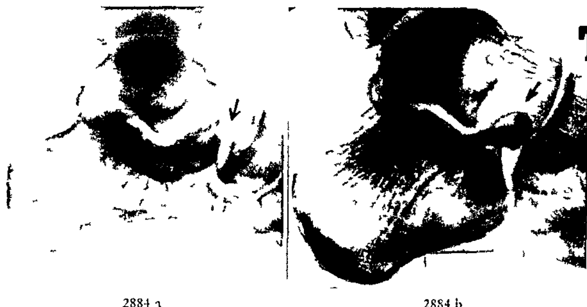
Fig 2883 July 6 1929—Tuber joint angle of 0° in a severe fracture of the calcaneus The tuber calcanei is displaced so far upward that the upper level of the tuber is higher than the level of the joint Longitudinal axis of the talus near the horizontal The lateral portion of the posterior joint surface has been driven downward (group 5) Partial dislocation between talus and navicular and between calcaneus and cuboid (group 7)



Fig 2884 July 6 1929 Negative tuber joint angle of 32° in a severely infected fracture of the calcaneus Severe decalcification The longitudinal axis of the talus is horizontal The lateral portion of the posterior joint surface has been driven downward Partial dislocation between the head of the talus and the navicular and between the navicular and the cuboid (group 7) Compare with figs 2859 2864—2875

action of the force on the joint surface is thus also influenced on age, on the density of the bone (normal or osteoporotic) on the muscular development and strength of the ligaments and on the character of the footing (hard, soft, smooth, uneven, level or inclined)

By the action of a small force, cracks (fissures) develop without displacement of the fragments The most frequently observed fissure extends from the sulcus calcanei obliquely downward in a frontal plane (figs 2893, 2899)



2884 a 2884 b

Fig 2884 a – Avulsion of a small bone fragment from the lateral side of the anterior upper edge of the calcaneus without significant displacement Sustained by turning the ankle on even ground Severe pain and effusion of blood Walking cast for 4 weeks

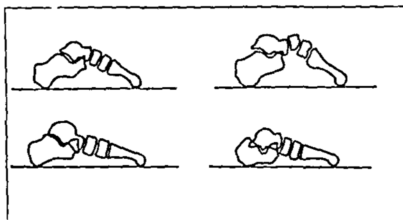
Fig 2884 b —Shearing off of a 20 mm fragment from the medial side of the anterior upper edge of the calcaneus Produced by maximal dorsiflexion of the foot in a fall while skiing Walking cast for 6 weeks At follow up examination after two years no symptoms and normal mobility *This roentgenogram was made available by Dr Gut St Moritz Switzerland*

There is then a split fracture resulting from the sudden impact of the wedge shaped lateral process of the talus and a simultaneous bending fracture because the lower posterior part of the tuber calcanei first touches the ground and is bent cranially The calcaneus thus sustains a crack in its weakest portion A frontal split fracture is seen relatively often which extends from the posterior joint surface almost vertically toward the sole This also results from the upward bending of the tuber as a result of the fall

When the force is greater the calcaneus is compressed between the vertical pressure of the posterior portion of the talus and the counter pressure of the ground like a hollow cylinder As a result of the compression the hollow cylinder bursts on both sides and a horizontal fracture extending from the sulcus calcanei to the dorsal surface of the tuber calcanei is produced (figs 2899, 2933) The ventral (toward the toes) portion of this fragment is forced more or less deeply into the spongiosa by the impact of the talus, while the dorsal (toward the heel) portion is tipped up so that a more or less wide gap results that sometimes resembles a duck-bill Due to the immediately following

elastic recoil of the talus the talocalcaneal joint space remains more or less widened (figs 2897, 2898, 2932, 2933, group 6) Sometimes the talus remains tilted up in front so that a subluxation between the head of the talus and the navicular results In these cases the talocalcaneal joint space remains narrowed (fig 2901, group 7)

As a result of the unique structure of the calcaneus which articulates medially with the talus and via the navicular and the cuneiforms with the three medial rays of the foot and laterally via the cuboid with the two lateral rays of the foot, an oblique sagittal shearing fracture is also simultaneously



2885—2888 Sketched February 14 1929

Fig 2885 Normal foot with slight forward inclination of the talus

Fig 2886 Pes cavus with horizontal position of the talus The navicular is wedge shaped High longitudinal arch

Fig 2887—Ordinary flat foot with marked inclination of the talus Flat longitudinal arch The anterior portion of the talus slipped downward on the medial side of the pronated calcaneus The navicular is pushed upward

Fig 2888 Flat foot after a fracture of the calcaneus The longitudinal axis of the talus is horizontal The posterior portion of the talus has been impacted into the body of the calcaneus The head of the talus is displaced upward and the navicular downward in Chopart s joint Compare with figs 2864—2875

produced by the vertical impact (fig 2858) This divides the joint space in two parts of which sometimes the medial and sometimes the lateral is the larger Sometimes several fractures extend through the joint surface Because often a primary oblique anterior frontal fracture has occurred, the fragment that has been separated by the horizontal fracture can be tilted downward in front (figs 2859, 2897)

More often a second oblique frontal fracture, which begins on the cranial surface of the tuber behind the joint surface and extends forward toward the sole in an oblique frontal plane, results from the bending up of the tuber A more or less broad piece of the lateral side of the joint surface is then forced downward to a greater or lesser degree and is subluxated in relation to the talus (figs 2857, 2893, 2922 group 5) The sustentaculum tali and the medial portion of the joint surface usually maintain their normal position in relation to the talus

action of the force on the joint surface is thus also influenced, on age, on the density of the bone (normal or osteoporotic), on the muscular development and strength of the ligaments and on the character of the footing (hard, soft, *smooth, uneven, level or inclined*)

By the action of a small force, cracks (fissures) develop without displacement of the fragments The most frequently observed fissure extends from the sulcus calcanei obliquely downward in a frontal plane (figs 2893, 2899)



2884 a 2884 b

Fig 2884 a Avulsion of a small bone fragment from the lateral side of the anterior upper edge of the calcaneu without significant displacement Sustained by turning the ankle on even ground Severe pain and effusion of blood Walking cast for 4 weeks

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2893 October 14 1929 2894

Fig 2893 — Mild fracture of the calcaneus An oblique fracture cleft extends from below anteriorly to above posteriorly through the base of the tuber calcanei and a second upward and forward The joint surfaces are not involved Tuber joint angle 10° (group 4)

Fig 2894 — Plantar dorsal view of same case The lateral wall is broken off and displaced laterally The sustentaculum tali is broken off medially with a long wedge but is not displaced The calcaneus is widened but not shortened





2895 January 17 1930 2896

Fig 2895 Same case after 12 weeks Good position and good callus formation Tuber joint angle 20° Reduced in the screw traction apparatus and with the calcaneus compression clamp Continuous traction for 4 weeks and *walking cast for 6 weeks The talocalcaneal joint space is* not narrowed Mobility normal

Fig 2896 — Same case dorsoplantar view to fig 2895 The calcaneus is again of normal width





2889 July 21 1928   2890 December 13 1927

Fig 2889 —Duck bill fracture above the transverse crest of the tuber calcanei and therefore above the insertion of the Achilles tendon (group 1 a) Sustained by a 69 year old stone mason when a heavy beam fell on his heel from behind while he was kneeling with his foot vertically supported on the balls of the toes Typical impaction fracture Calcification of the arteries This fracture type is very rare

Fig 2890 —Isolated fracture breaking off the sustentaculum tali The fragment is displaced medially Sustained in a 1 M fall on the strongly supinated foot Typical shearing fracture At the same time the tip of the lateral wedge of the talus was avulsed This fracture type is very rare (group 3)



2891   May 9 1929   2892

Fig 2891 —Fracture of the medial process of the tuber calcanei with minimal medial and upward displacement of the fragment This fracture type is common (group 2) see fig 2855 u

Fig 2892 —Plantar exposure of same case The position of the fragment on the medial side can now be determined in this view see fig 2855 t





2901 January 26 1931 2902

Fig 2901 — Comminuted fracture of the calcaneus Tuber joint angle negative The lateral portion of the posterior joint surface of the calcaneus is forced downward and subluxated while the medial portion with the sustentaculum tali has remained in its normal position (group 5) The tuber calcanei is split horizontally The longitudinal axis of the talus is horizontal and the head of the talus subluxated upward in relation to the navicular or the entire foot is subluxated downward in Chopart's joint (group 7) The anterior portion of the calcaneus is also comminuted and the fragments are displaced in relation to the cuboid (group 8)

Fig 2902 — Oblique plantar view to fig 2901 The lateral wall is broken off and pushed forward laterally and medially the sustentaculum tali is broken off with a medial wedge The medial portion of the posterior joint surface of the calcaneus is well shown The lateral on the other hand is not because it is displaced downward The tuber calcani is adducted producing a medially open angle





2903 January 26 1931 2904

Fig 2903 — Same case dorsoplantar exposure of the talonavicular joint The anterior portion of the calcaneus is comminuted and subluxated laterally in relation to the cuboid (group 8)

Fig 2904 — Same view of the sound side The uninjured joint between the anterior process of the calcaneus and the cuboid is well shown





2897 May 20 1931 2898

Fig 2897 — Severe comminuted fracture of the calcaneus Tuber joint angle negative Broad gap between the posterior joint surfaces of the talus and the calcaneus an indication that the entire posterior joint surface of the calcaneus is tipped and subluxated downward Longitudinal fracture through the tuber calcanei and longitudinal fracture through the anterior portion of the calcaneus No displacement in relation to the cuboid (group 6)

Fig 2898 — Same case dorsoplantar view The bone is markedly widened and shortened The lateral wall is driven forward Medially the wedge extending back from the sustentaculum tali is comminuted The posterior joint surface of the calcaneus is markedly displaced downward more medially than laterally





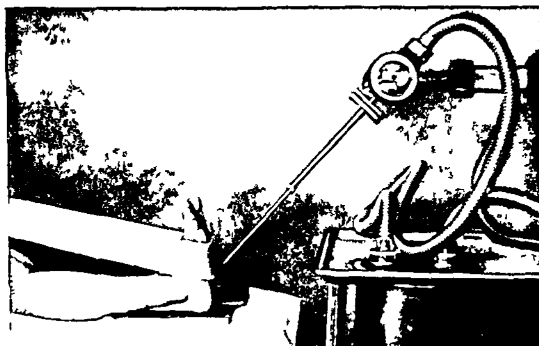
2899 May 20 1931 2900 November 17 1931

Fig 2899 Same case after tenotomy of the Achilles tendon reduction with the Phelps Gocht osteoclast and compression with the calcaneus compression clamp The tuber joint angle is 5° The posterior joint surface of the calcaneus which had been displaced downward is again in normal position in relation to the talus

Fig 2900 — Same case after 6 months The widening has re appeared

Lateral displacements occur chiefly in the sagittal plane, namely in a cranial direction The tuber can be displaced cranially by a few millimeters (figs 2947), by half its width or even by its full width (figs 2951, 2955, 2957)

Shortening is common It results from the impaction of the fragments (fig 2860) Fractures with lateral displacements usually show no significant shortening (figs 2947, 2957) In figs 2829 and 2855 the calcaneus is even elongated



2907 October 28, 1929

Positioning of the foot for the plantar dorsal roentgen exposure of the calcaneus Heel and lower leg are on the film cassette The patient pulls his foot in dorsiflexion with a strip of bandage The central ray of the roentgen tube is directed at the posterior portion of the calcaneus

Rotation of the fragments in relation to each other is rare Sometimes the tuber is rotated in pronation or supination in relation to the body of the calcaneus to a minimal degree

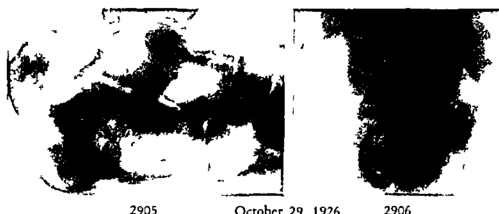
Diagnosis of Fractures of the Calcaneus

As I have seen from various reports in the literature and from my own experience, fractures of the calcaneus are often overlooked even though their diagnosis is very easy They are often considered malleolar fractures or as sprains of the ankle and treated for months with compresses, hot air, massage, passive motion and various types and colors of irradiations

The history of a vertical fall from a height of more than 0 5 M immediately indicates the possibility of such a fracture Then the inability to walk further, the flattening of the plantar arch, the inability to pro- and supinate while the mobility of the ankle joint remains nearly normal and the

The lateral wall of the body of the calcaneus is split off by the impression of the lateral portion of the joint surface and an additional sagittal longitudinal fracture results (figs 2856, 2858) The calcaneus is thus broadened and as a result is also shortened (figs 2856, 2858, 2859) The split off lateral wall is palpable below the lateral malleolus as a bony hard protrusion While the calcaneus *is normally 30 to 35 mm wide in the plantar-dorsal roentgenogram* it may be 40 to 70 mm wide after a fracture (figs 2856, 2858, 2860, 2872, 2874)

The typical fracture lines can be seen well marked without displacement in figures 2893 and 2894, namely the anterior oblique frontal, the medial sagittal and the lateral sagittal



2905 October 29 1926 2906

FIGS 2905 2906 —Comminution and avulsion of the tuber calcanei Such fractures occur only in diseased bones as for example in tabes poliomyelitis or in the presence of bone atrophy from various cause

When the sagittal fracture lines extend through the anterior process of the calcaneus into the calcaneo cuboid joint comminution and subluxation may result (fig 2903, group 8)

By the action of an especially great force the talus is forced between the fragments of the calcaneus until it reaches the sole (fig 2951), and it may also be fractured as in fig 2829 Sometimes one can count up to 20 fragments of the calcaneus It then feels like a bag of shot

The various fracture forms and displacements depend on whether the impacting, the shearing or the bending force is greater, and on how they are related to each other and how they follow one another Despite the profusion of their forms a certain order is present

Displacements Angulation is the commonest of the four displacements (angulation lateral displacement shortening and rotation) The tuber calcanei is angulated in relation to the body of the calcaneus in the sagittal plane and is displaced backward and upward so that an angle is formed that is open cranially (figs 2857, 2859, 2884) In addition angulations occur in the horizontal plane namely in that the posterior fragment is bent medially and a medially open angle results (figs 2860 2898 2902)

to the lateral malleolus and obtains four exposures, namely, with inclination of the central ray of 10°, 20°, 30° and 40° The exposure obtained at an angle of 10° shows the posterior part of the talocalcaneal joint while the joint between the talus and the sustentaculum tali is often seen on the exposures obtained at 20° and 30° and the joint of the anterior portion of the calcaneus at 40°

Leitner[1] places the foot on its lateral side in dorsiflexion at the ankle and inclines the central ray 45° towards the heel and 15° dorsalward

Anthonsen[2] placed the foot on the film cassette on its lateral side and focuses the central ray on the tip of the medial malleolus with an inclination of the central ray of 25° to 30° from cranial to distal and 25° to 30° from dorsal to ventral The central ray of the X-ray tube strikes the posterior portion of the joint tangentially and in addition the longitudinal axis of the sulcus calcanei

We formerly designated the plantar dorsal roentgenograms as *axial* This term was not correct as it actually is a picture taken from in front below, toward in back above in the sagittal plane The posterior two thirds of the calcaneus and with correct positioning the talocalcaneal joint can be demonstrated Only those roentgenograms that are made in the direction of the longitudinal axis of the calcaneus can be considered *axial* This is the case with all antero-posterior (a p) exposures of the ankle joint These exposures are however usually worthless for evaluation of the calcaneus, because the talus is superimposed over the entire bone In figures 2236, 2237 for example one sees axial views of the patella

Tuber-joint Angle

Normally a straight line that connects the highest point of the anterior upper joint surface with the highest point of the posterior joint surface of the calcaneus intersects a second straight line that extends along the upper surface of the tuber at an angle of 140° to 160° The supplementary angle subtends 20° to 40° Because this acute angle is easier to measure and to estimate with the naked eye, I have called it the *tuber-joint angle* (figs 2876 2877, 2881) After a fracture of the calcaneus this angle becomes smaller, disappears entirely or becomes negative (figs 2882—2884)

In the tuber-joint angle we have an exact measurement of the type and severity of the fracture, the extent of the reduction and the further course It depends primarily on the shape of the bone Function can however be poor in spite of restoration of this angle if the displaced joint surfaces are not replaced

Possible Complications of Fractures of the Calcaneus

The most frequent complications are (1) the decalcification that as a rule disappears again, (2) painful arthroses chiefly in the talocalcaneal joint and (3) traumatic flatfoot

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[1] Leitner Unsere Technik der Rontgenaufnahmen bei der Luxatio pedis sub talo Fortschr Rontgenstrahl 77 92—96

[2] Anthonsen An oblique projection for roentgen examination of the talocalcaneou joint, particularly regarding intra articular fracture of the calcaneus

extravasation of blood that spreads toward the sole of the foot after a few hours which never occurs in malleolar fractures The extravasation of blood may extend up to the knee In severe fractures the malleoli lie nearer the sole of the foot and the ground *The most important finding is the tenderness to pressure which is limited to the calcaneus* If one grasps the calcaneus between the thumb and forefinger usually severe pain is produced With this maneuver one can sometimes also detect a perceptible grating and cracking The type of fracture can only be established by a roentgenogram

Roentgen Technique in Fractures of the Calcaneus

For treatment and prognosis it is necessary to recognize the exact type of fracture This is only possible with good roentgenograms Four exposures are necessary for an ordinary fracture of the calcaneus, namely

1 A lateral (frontal) exposure of the injured side (figs 2882—2884) For the lateral exposure, we always lay the foot on the lateral side and focus the central ray of the X-ray tube 1 cm below the medial malleolus Usually we use an 18 × 24 cm film for the lateral and the anterior exposure
2 An anterior (sagittal) exposure taken obliquely from plantar to dorsal (fig 2860) This is made as follows The patient lies down and pulls upward on a *sling that is placed about his forefoot* The cassette with the film is placed under the heel and the central ray of the X-ray tube is focussed at a 45° angle on the middle of the plantar aspect of the foot (fig 2907) We formerly made this exposure in the standing patient from posteriorly above to anteriorly below, namely in dorsoplantar direction This however gave rise to many difficulties when both calcanei were fractured or when other severe injuries were present and was impossible immediately after reduction
3 For comparison a lateral (frontal) exposure of the sound side (fig 2881)
4 For comparison an anterior (sagittal) oblique plantar-dorsal exposure of the sound side (fig 2879)
5 When the lateral roentgenogram of the injured side shows comminution of the anterior portion of the calcaneus or a partial dislocation in Chopart s joint, a fifth exposure must be made dorsoplantar of the proximal part of the foot Both feet are placed next to each other on the film cassette in plantar flexion (figs 2903, 2904)
6 In order to obtain a clear view of the talocalcaneal joint especially of its posterior portion the lower leg together with the foot is rotated outward 45° according to Hallgrimsson [1] The central ray is focused on a point 2 cm below and anterior to the medial malleolus at an angle of 10°—20° toward the heel

Broden , with the ankle joint at right angles and the lower leg and foot in inward rotation of 45° focuses the central ray on a point 2 cm below and anterior

[1] Hallgrimsson Studies on reconstructive and stabilizing operations on the skeleton of the foot Acta chir scandinav *88* suppl 78 1943

Broden Roentgen examination of the subtaloid joint in fractures of the calcaneus Acta Radiol *31* 85 1949

when the infection appears early before the fragments are adherent to each other and the infection can spread into all fracture spaces These result from extension or transfixion pins or wires that have been inserted into the wrong place (figs 2921 a b) and have not been conscientiously observed In addition infections follow operative reduction Fatalities, amputations, sequestration and persistent fistulas may result Gollasch has emphatically described infections and their causes on pages 2108—2114 Sudeck s syndrome often follows infection

Usually excessive traction during reduction and during further treatment is the cause of Sudeck's syndrome The talocrural and talocalcaneal joint are pulled apart and the ligaments are damaged When the distraction that has been thus produced is continued by use of excessive weights or by a transfixion cast, a severe spotty bony atrophy develops and muscle atrophy with fibrosis appears especially in the short muscles of the foot with resulting pes cavus and contractures of the toes with production of hammer toes In addition the ligaments and joint capsule shrink In this manner marked limitation of motion appears All of the complications described in Vol I/pp 26, 27 can result from distraction

Avoidance of Complications Following Poorly Managed Treatment Infection can be avoided if one immediately removes pins and wires used for traction as soon as the slightest signs of inflammation appear, and if transfixation and operative reduction are avoided as much as possible The dystrophies that follow the use of traction with excessive weights can be easily avoided if never more than 3 kg are used Limitation of motion in joints other than the talocalcaneal, hammer toes, and pes cavus do not then follow The incidence of arthroses is then also less

General Considerations in Treatment of Fractures of the Calcaneus

In order to achieve a good result fractures of the calcaneus must be treated in exactly the same manner as all other fractures, namely, they must be exactly reduced and the well reduced fragments must be continuously immobilized until they have united by bony union During the time of immobilization as many joints as possible and the entire body should be exercised

Reduction Angulations as well as shortening with its associated broadening of the calcaneus are maintained and increased by muscle pull, the angulation with the cranially open angle by way of the Achilles tendon by its muscles and the widening and shortening by the short muscles of the sole These muscles work as a parallelogram of forces and their pull can only be overcome when a force is applied in the direction opposite the direction of the resultant (figs 2908 2909) Since the resultant corresponds to the longitudinal axis of the normal calcaneus, the shortening and the angulation can often be simultaneously corrected by traction in this direction Vol I/figs 1—6, and figures 2910, 2911 show the action of the calf muscles in the normal and in the fractured calcaneus and the influence of the various positions of the joints The widening of the calcaneus is corrected by appropriate pressure from both sides with the heels of the thumbs or with the calcaneus clamp (figs 2920,

If fractures of the calcaneus with displacement are not reduced and continuously immobilized for a sufficient length of time permanent disability often results The plantar arch is flattened, the heel is markedly widened, gait is disturbed, and often persistent pain remains especially when treading on uneven ground Walking on the balls of the feet is difficult Figures 2947 and 2948 show how even in the teen aged marked arthrotic changes can appear in the talocalcaneal and talonavicular joints as early as four years after a relatively mild fracture of the calcaneus When the calcaneus is markedly widened arthroses at the tip of the lateral malleolus also appear That apparently insignificant fractures of the calcaneus of group 4 sink together on weight bearing if they are not fixed can be seen in figs 2949 and 2950 In addition marked decalcification occurs *The chief complaints stem from arthroses of the talocalcaneal joint*

Traumatic Flat-foot After Fractures of the Calcaneus Traumatic flat-foot follows all severe fractures of the calcaneus This is completely different from the ordinary type of flat-foot which results from a sinking and inward rotation of the head of the talus while the posterior portion of the calcaneus assumes a position of pronation and abduction (fig 2519 b) On the other hand, after a fracture of the calcaneus the body of the talus sinks into the comminuted calcaneus while the head of the talus is elevated, in fact sometimes to such a degree that the ligaments between the talus and navicular rupture (figs 2888, 2901) The cuboid is also usually displaced downward together with the navicular so that there is a partial dislocation in Chopart s joint In addition the posterior portion of the calcaneus is often adducted (figs 2860, 2902)

Prevention of Complications Following Fractures of the Calcaneus By exact reduction and immobilization for an adequate length of time good form of the foot can always be achieved and good mobility sometimes also can result The marked decalcification can be avoided especially in the milder cases if distraction is avoided Arthroses in the talocalcaneal joint are often unavoidable in severe fractures of groups 5—8

Possible Complications of Unsuitable Treatment

Various methods of treatment of fractures of the calcaneus have been discredited becau e they have been poorly carried out and because the results then were much worse than without treatment Some surgeons therefore avoid any attempt at reduction using a Steinmann pin or Kirschner wire traction or open reduction and only apply a cast Others have even given up cast immobilization and allow the patient to get up and bear weight already after 2 to 3 weeks Kerstner[1] has written a very good report of current methods of treatment in Germany

Inadequate reduction and too short a period of traction are among the worst types of treatment The result cannot then be better than without reduction with its associated loss of time and hazards The worst dangers are *infection* and *Sudeck s atrophy* The sequels of *infection* are especially severe

[1] Kerstner Der derzeitige Stand der Fersenbeinbruchbehandlung Zbl Central Chir *80* 360—373 1955

when the infection appears early before the fragments are adherent to each other and the infection can spread into all fracture spaces These result from extension or transfixion pins or wires that have been inserted into the wrong place (figs 2921 a, b) and have not been conscientiously observed In addition infections follow operative reduction Fatalities, amputations, sequestration and persistent fistulas may result Gollasch has emphatically described infections and their causes on pages 2108—2114 Sudeck s syndrome often follows infection

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2921) In the less severe cases it is thus possible also to replace the displaced joint surfaces

Uninterrupted Immobilization of the Reduced Fragments

In fractures of group 2 and 3 immobilization after reduction is very simple since as a rule no muscles are present that produce redisplacement Reduction in shearing, impaction and comminuted fractures of groups 4—8 with partial or complete dislocation of the fragments in the region of the upper joint surface (groups 5—8, figs 2860, 2861, 2897—2904) is sometimes exceedingly difficult and *uninterrupted* immobilization of the reduced fragments until they have united with each other is even more difficult, since the duration of healing is fairly long in these fractures (10 to 12 weeks) and the associated dangers are large, because in severely comminuted fractures position of the fragments can only be maintained for longer periods of time if traction using clamps, *pins or wires is applied to the bone itself or if the reduced fragments* are transfixed by wires *In fractures in which the superior joint surface cannot be reconstituted early arthrodesis is the most satisfactory treatment*

History of the Treatment of Fractures of the Calcaneus as Practiced by Me

Over the last 40 years my assistants and I have treated over 1800 fractures of the calcaneus We have used the most varied forms of treatment In 1917 I treated 4 cases by continuous traction using the Schmerz clamp and 3 Kg weight on the Braun splint in a similar manner as in lower leg fractures (fig 2374) The clamp remained in place 8 to 10 weeks The results were good These were moderately severe cases in soldiers between the ages of 20 and 30

In 1921 I[1] changed over to reducing the fracture under local anesthesia with the knee at a right angle or an acute angle and plantar flexion at the ankle joint The tuber was then pressed downward and the widened calcaneus pressed together and after pressing away the swelling an unpadded cast was applied Wendt[3] in 1953 advocated similar principles In the milder cases the results were good but in the more severe cases permanent disability remained because I removed the cast too early and because the fragments therefore redisplaced

In 1926 I[4] returned to continuous traction with the clamp and corrected the broadening of the calcaneus with calcaneus compression clamp Since in several cases the fragments again spread out I changed over to pulling down the tuber calcanei in the screw traction apparatus, compressing the calcaneus with the calcaneus compression clamp, immediately applying a non-padded cast and continuing traction with 3 Kg for 3—5 weeks followed by a lower leg walking cast for an additional 7—8 weeks Many of the cases so treated

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1 Bohler L Anatomische und mechanische Grundlagen fur die Einrichtung und Behand lung von Fersenbeinbruchen Arch klin Chir *126* 398—417 1923 (photos and drawings on pp 414 415)

— Die Behandlung der Fersenbeinbruche und die Behandlung des traumatischen Platt fußes Z orthop Chir *45* 415—421 1924

3 Wendt H Extreme Muskelspannung in der Behandlung von Fersenbeinbruchen Zbl Chir *78* 153—160 1953

4 Bohler L Behandlung der Fersenbeinbruche Arch klin Chir *157* 723—732 1929

showed very good results In some however the tuber-joint angle became smaller in the walking cast because the traction was discontinued too soon

In 1927 I introduced the concept "tuber-joint angle"

In 1930 instead of using continuous traction I[1, *] carried out reduction in the screw traction apparatus with a pin driven through the os calcis and a second through the tibia (fig 2941), compressed the calcaneus with the calcaneus compression clamp (fig 2921) and applied a plaster cast (transfixion) After 3 to 5 weeks the cast and the pins were removed Then a walking cast without pins was applied for an additional 7 to 8 weeks The results were similar to those achieved by continuous traction after compression with the calcaneus clamp and later application of the walking cast

Since a severe infection occurred once as a result of faulty technique, I removed both nails after the application of the cast for a time The results in many of these cases were bad because the tuber-joint angle again became smaller or disappeared altogether in spite of good reduction and in spite of exact molding of the cast and because a redisplacement of the joint surface also occurred leading to arthrosis of the talocalcaneal joint

Several cases of group 6 (figs 2897, 2832) could not be completely reduced in the screw traction apparatus but position could be achieved with the Phelps-Gocht osteoclast (fig 2899) Because this method of reduction was very easy I applied it for a time to all groups The good position however disappeared soon as the follow up examination showed, because the Achilles tendon pulled the tuber calcanei up again in spite of the carefully moulded cast Therefore I subsequently divided the Achilles tendon obliquely or in step fashion in 12 cases Nevertheless at follow-up examination it was seen that in spite of division of the Achilles tendon in some cases the tuber-joint angle that was restored by the reduction became smaller or disappeared on weight-bearing These patients could walk or stand on tip toe only with difficulty and showed arthroses in the talocalcaneal joint Therefore I abandoned this method

It just is not enough to reduce the comminuted calcaneus accurately In order to achieve good usability the reduced fragments must be *continuously* immobilized until they have united in bony union This requires 10 to 12 weeks depending on the severity of the injury

The continuous immobilization of the fragments is only possible if one exerts continuous traction directly on the bone by means of pins, wires or clamp or if one applies a long cast with maximal muscle relaxation according to Wendt (the foot in plantar flexion and the knee at a right angle) The non-padded lower leg cast alone is not sufficient to maintain the good position even in mild fractures of group 4

In 1935 following the suggestion of Westhues[3] we began reduction of the fractures in groups 4—8 using a Steinmann pin driven into the calcaneus

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[1] Bohler L Diagnosis Pathology and Treatment of Fractures of the Os Calcis J Bone Surg *13* 75—88 1931

[*] — Les Fractures du calcaneum 44 Congres francais de Chirurgie 1934

[3] Westhues H Eine neue Behandlungsmethode der Calcaneusfrakturen Zentralbl Chir *62* 995—1002 1935

from behind and applied a walking cast over this We have abandoned this method because inflammation of the point of entry of the posterior pin often resulted and because a painful horny scar usually formed at this point We frequently use this sagittally introduced pin for reduction and immediately remove it again as soon as the position is satisfactory

Subsequently we reduced fractures of groups 5—8 either with the Phelps-Gocht osteoclast or more often in the screw traction apparatus Then we applied a cast under *continuing traction for 6 weeks Thereupon the nail* was removed, and a lower leg walking cast was applied for an additional 6 to 8 weeks

As early as 1938 in the fifth edition of this book I advocated arthrodesis of the talocalcaneal joint for painful arthrosis

Since 1938 we carried out reduction at once in suitable cases and not after 8 to 10 days, after the swelling had receded Reduction was carried out in *the screw traction apparatus and continuous traction with 5 Kg was applied* for 6 weeks Since 1939 we no longer apply a cast but rather use traction alone This has the advantage that beginning signs of inflammation can at once be discovered and the nail removed Then a lower leg walking cast was applied for an additional *4 to 6 weeks* Traction using 5 Kg was too much in the absence of a cast Pes calcaneus or hook foot' resulted, which we tried to avoid with a plaster splint that left the heel free A worse problem was that all signs of Sudeck's atrophy (decalcification, hammer toes, pes cavus) sometimes appeared as result of excessive traction

Since 1943 we limit the weight used for continuous traction to 3 Kg

In 1948 we treated 10 cases operatively according to the suggestion of Ivar Palmer [1] and bolstered the joint with bone chips similar to the technique used earlier by Lenormant [2] The operation is not easy The results were good Ender [3] has reported these We have abandoned the method because we observed infections in cases that had been operated upon elsewhere At follow up examination of these cases after 8 years we found that the majority had gotten worse because arthroses had developed in the talocalcaneal joint Widen who carried out the follow-up examinations on the patients operated upon by Palmer reported good long term results

Since 1955 we have treated 19 patients by reduction in the screw traction apparatus and fixation of the fragments by percutaneously introduced Kirschner wires (figs 2922—2939) We have abandoned this method, because the correct placement of the wires is difficult and especially because we have seen minimal secretion at the point of insertion of the wires in 3 cases In reviewing the

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1 Palmer I The mechanism and treatment of fractures of the calcaneus J Bone Surg *30 A* 1—7 *1948*

2 Lenormant C P Wilmoth Lecoer A propos du traitment sanglant des fractures du calcaneum Bull et mem Soc nat de chir *54* 1353 1928

3 Ender J Knochenspanunterfutterung bei frischen Fersenbeinbruchen Wien med Wchnschr *100* 267—270 1950

literature we found that Moberg[1] has described this method with subsequent arthrodesis already in 1951

Since 1956 we carry out reduction when possible already on the first day using the screw traction apparatus and correct the widening of the calcaneus with the calcaneus compression clamp as we did already in 1926 If the superior joint surface has sunk down, it is lifted with a sagittally introduced pin according to the method Westhues Then traction is exerted by means of a transverse pin through the calcaneus After 8 to 10 days a long cast is applied with the foot in extreme plantarflexion and the knee at a right angle in order to achieve maximal muscle relaxation for an additional 4 weeks and then a lower leg walking cast for an additional 4 to 6 weeks if it has been possible to completely restore the superior joint surface as in figures 2922—2939

Since 1956 in cases in which complete restoration of the talocalcaneal joint was not achieved following the suggestion of Ehalt[2] we have performed early arthrodesis using a three-flanged nail (fig 2962 a—d) Many patients are able to walk without a cast in an Unna's paste boot as early as in the third week after operation Ehalt[3] has used early arthrodesis since 1951

The results were unsatisfactory with all methods of treatment in which the fragments were not continuously immobilized by skeletal traction

I have employed so many forms of treatment in such extended series because formerly I was unable to separate the various types of fractures of the calcaneus sharply from one another Not until I classified the various fractures into groups was I able to determine why with identical treatment one fracture yielded a good result while another yielded a poor result The influence of the various methods of treatment on the result was first fully clarified when Jimeno Vidal in eight months intensive work reviewed my 182 fresh cases from the years 1926 to 1932 and considered the 2300 roentgenograms from different points of view working them through completely six times For example in all the tuber-joint angle was determined before reduction, after reduction, after removal of the traction or the pin and again after 4, 8, 12 and 16 weeks, after ½ year and after 1 to 5 years He discovered that certain types of fractures were restricted to certain age groups The oft described avulsion fractures of the tuber calcanei from the pull of the Achilles tendon did not occur in the presence of normal bone They occurred in the presence of decalcification as a result of age or disease and in the presence of neurological disturbances as tabes and poliomyelitis

Subsequently Gollasch carried out a similarly thorough follow-up examination of the 247 fresh cases of the 10 years 1926—1935 He contacted all of the survivors and was able personally to examine 92% clinically and radiologically The results are presented on pages 2108—2114

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[1] Moberg M E Comminuted fractures of the calcaneus with joint injuries Congres internat de Chir Orthop et Traumat *5* 632—637 1951

[2] Ehalt W and S Zerlauth Behandlungsergebnisse frischer operierter Fersenbeinbruche Ztschr Orthop u Grenzgebiete *88* 109—121 1956

[3] Ehalt W Fractures of os calcis primary fusion combined with reconstruction Congres internat de Chir Orthop et de Traumat *5* 638—639 1951

The most important finding that we were able to discover was the fact that in cases with marked comminution it was only possible to maintain the position of the well reduced fragments if they were held with one or two pins or wires in plaster, or one pin in continuous traction, or with buried Kirschner wires, or by extreme muscle relaxation until they had united

I have described all methods of treatment employed by me since 1917 in order that others may avoid disagreeable complications

Numerous exhaustive reports have appeared concerning the etiology and treatment of fractures of the calcaneus The best are those of Paitre and Boppe,[1] Ahlberg, Gollasch,[3] Belenger, Van der Elst, Lorthioir,[4] and Widén[5]

Treatment of Fractures of the Upper Portion of the Tuber Calcanei (Group 1 a—c)

The mechanism of production of fractures of group 1 a—c is described on pages 2047, 2048 The treatment is variable depending whether the fracture is cranial (group 1 a) or caudal (group 1 b, 1 c) to the insertion of the Achilles tendon

Treatment of Fractures of Group 1 a with the Fracture Line Cranial to the *Insertion of the Achilles Tendon*

(Figs 2855 m, 2889, 2912, 2913)

The *same things are required for reduction and treatment as for malleolar fractures* (see p 1917) After local anesthesia the swelling and hematoma are pressed away as much as possible Then the Achilles tendon is relaxed by marked plantarflexion of the foot and by bending the knee (Vol I/figs 1—6 and fig 2912) It is then usually possible to replace the fragment which has been tipped cranially

First Roentgen Check One determines whether the reduction has been successful with a lateral view If the position should not be satisfactory the reduction should be repeated

Immobilization When the roentgenogram shows that the reduction wa satisfactory, a temporary lower leg cast is applied at plantar flexion of 95° to 100° as for malleolar fracture It must be immediately split including the last thread (see pp 1920—1927)

Second Roentgen Check A lateral roentgenogram is made after the application of the temporary cast in order to determine whether or not the position remained good

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1 Paitre F and Boppe M Les fractures du calcanéum Congres francais de Chir *26* 147—405 1935

2 Ahlberg A Studien uber 111 nachuntersuchte Fälle von Calcaneusfrakturen unter besonderer Berucksichtigung der Gelenksschaden zwischen Talus und Calcaneus Elanders Boktryckeri Goteborg 1940

3 Gollasch W Behandlungsergebnisse von 250 Fersenbeinbruchen Hefte Unfallheilk *31* 1—163 1941

4 Belenger M Vander Elst E Lorthioir J Les fractures du calcanéum leur traitement et le traitement des sequelles Acta orthopedica belgica *57—168* 1951

5 Widén Anders Fractures of the calcaneus Acta chir scandinav Supplement *188* 1—119 1954

Application of a Lower Leg Walking Cast After a week a short leg walking cast is applied at 95° to 100° plantarflexion as for a malleolar fracture (see pp 1928—1932) It is removed 6 weeks after the injury and is replaced with an Unna's paste boot (see Verbandlehre, pp 70—84)

Operative Removal of the Fragment If it is not possible to replace the fragment in its bed and if it presses forcibly against the skin, it can be removed by an incision on the lateral aspect of the Achilles tendon If it is distinctly cranial to the insertion of the Achilles tendon it should not be fixed with screws or sutured into place because often skin necrosis occurs following operation

Treatment of Fractures of Group 1 b Caudal from the Insertion of the Achilles Tendon (figs 2855 n—qu)

Here it is important to release the tension on the markedly stretched skin as soon as possible in order to prevent necrosis Reduction is attempted with the Achilles tendon relaxed in the same way as in fractures of group 1 a (see p 2074) If the first roentgen check shows that reduction has not been completely successful the upper edge of the fragment is grasped with a single pronged hook which is introduced percutaneously The fragment is then pulled down into position

Immobilization When the two lateral roentgenograms show that reduction is complete, a temporary long cast is applied with the foot in 120° plantarflexion and the knee at 90° flexion in the manner recommended by Wendt (see p 2095) This is immediately split through the last thread

Third Roentgen Check After the application of a temporary long leg cast a lateral roentgenogram is made

Closure of the Split Long Cast When the swelling has receded after 6 to 8 days the split long cast is pulled together tightly with a muslin or gauze bandage

Fourth Roentgen Check After a week a new lateral roentgenogram is made If it shows good position the cast is left in place Otherwise the displaced fragment is replaced and fixed with two Kirschner wires or a screw (see below)

Fifth Roentgen Check Five weeks after injury a new lateral roentgenogram is made in order to determine if the good position has been maintained

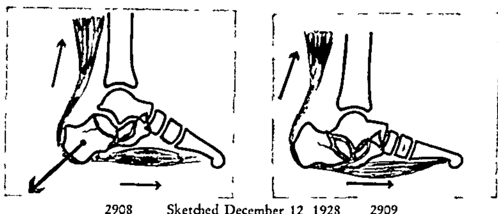
Shortening of the Temporary Long Cast If the roentgenogram shows good position, the thigh and knee parts of the temporary cast are removed and the leg is placed on a Braun splint for 3 to 4 days and then positioned with the knee extended for an additional 3 to 4 days

Sixth Roentgen Check and Application of the Lower Leg Walking Cast When the new roentgenogram shows that the fragment has not become redisplaced in spite of the extension in the knee joint, a lower leg walking cast is applied in the manner described on page 1928, but with the foot at 110° plantarflexion

Seventh Roentgen Check After the application of the lower leg walking cast a new lateral roentgenogram is made in order to determine whether the fragment has become displaced

Removal of the Lower Lel Walking Cast Eighth Roentgen Check and Application of an Unna's Paste Boot The lower leg walking cast is removed after 4 weeks, that is, 10 weeks after the injury Then the eighth roentgenogram is made and an Unna's paste boot applied until the swelling disappears

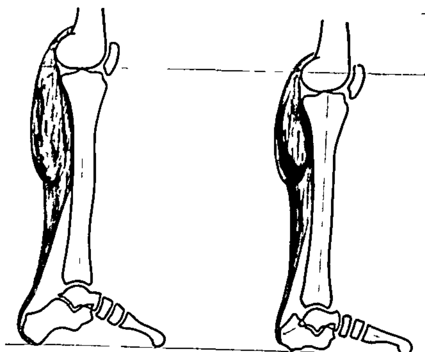
Fixation of the Reduced Fragment with two Kirschner Wires or with a Screw If the fragment becomes redisplaced in the temporary long cast,



2908 Sketched December 12 1928 2909

Fig 2908 —The muscles of the Achilles tendon pull the posterior fragment upward and thus increase the angulation with the cranially open angle The muscles of the sole pull forward and increase the shortening and widening

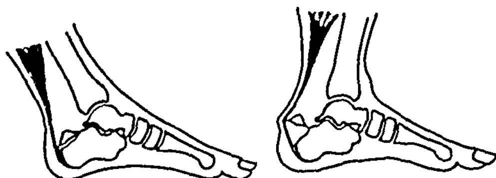
Fig 2909 —The calf and sole muscles pull in a parallelogram of forces Their action can only be nullified by traction in the opposite direction of the vector of these two forces



2910 Sketched December 12 1928 2911

Fig 2910 —Normal lever relation hip between the calcaneus and the calf muscles

Fig 2911 —After fracture of the calcaneus it has become shorter and lower Since the lever at the posterior process of the calcan us and th entire leg has become shorter the calf muscles are relatively too long and therefore these patients can no longer walk on tip toe as previously or as on the sound side and the foot is unable to develop its normal rolling movement They tire quickly



2912 Sketched December 12 1928 2913

Fig 2912 —If the foot is plantarflexed the Achilles tendon clears the fragment In this position it can easily be reduced and reduction maintained It should not be fixed with a wire loop because the fragments must be too widely exposed and nutritional disturbance of the bone and the skin may result

Fig 2912 — In dorsiflexion of the foot the fragment is tipped upward about a transverse axis





2913 a September 3 1956 2913 b October 17 1956

Fig 2913 a —Duck bill fracture of the left calcaneus cranial to the transverse crest of the tuber calcanei (group 1 a) Sustained by a 69 year old woman who slipped on a stair The small fragment is tipped vertically and displaced dorsally Thin bone and periosteum fragments are folded over the fracture surface from the dorsal surface of the calcaneus as in fig 2855 o

Fig 2913 b —Same case after reduction and fixation of the fragment with a screw The screw was initially introduced too far dorsally Screw fixation would not have been necessary in this case

it should be fixed with two Kirschner wires or with a screw The patient is placed face down The leg is then bent to a right angle at the hip and at the knee, and the lower leg is placed on a low table or on a chair, in order to relax the Achilles tendon by plantar flexion After the fragment has been exactly replaced with finger pressure or with a one-pronged hook and the reduction has been verified by a roentgenogram, two wires are inserted through the skin parallel to the cranial surface of the tuber calcanei so that they come to lie at right angles to the Achilles tendon If the wires are inserted obliquely toward the sole, there is danger that they may be pulled out by the pull of the Achilles tendon A screw may be used in place of the wires It must be

inserted through a small skin incision at right angles to the fracture line (fig 2913 b) Two drill bits are inserted next to one another so that the fragment remains in place when one drill bit is removed in order to insert the screw into the hole After the operation a temporary lower leg cast is applied with the foot in 120° plantarflexion This is immediately split through the last treated After 4 weeks a lower leg walking cast is applied in normal position After 8 weeks an Unna's paste boot is applied

Operative Exposure of the Fragments and Fixation with Screws or Wire Suture If it is not possible to fix the fragment percutaneously with screws or with Kirschner wires, it must be exposed A dorsal longitudinal incision should not be used, because the skin over the tuber calcanei is atrophic and thin and not infrequently becomes necrotic, as I know from personal experience as well as from the literature Sequestration and prolonged disability may result Therefore since 1928 I have utilized a longitudinal incision on the lateral and on the medial side of the Achilles tendon, replaced the fragment and fastened it with a wire loop that led around the plantar surface of the calcaneus If the wire was placed through the atrophic bone it sometimes cuts through the atrophic bone when pulled tight, because this is sometimes so soft, that it can be perforated by a heavy needle or a knife Further treatment with a temporary lower leg cast and subsequent walking cast is carried out as for malleolar fracture (see pp 1920—1932)

In the future it will probably be possible to carry out reduction using fluoroscopy with the electronic image intensifier without danger of X-ray burns to patient or physician The image intensifier intensifies the roentgenogram *800 times By this means roentgen checks 1, 2, 4 and 5 can be omitted* This kind of flouroscopy will be especially useful for the introduction of the wires and screws The other roentgenograms 3, 6, 7 and 8 as well as 9 at the *time of discharge should however be made in order to maintain a permanent* record

Treatment of Fractures of Group 1 c in Which the Fracture Cleft is Distal to the Insertion of the Achilles Tendon (figs 2855 r and s)

In contradistinction to the duck bill fractures of group 1 b the skin is not endangered by pressure from a projecting bone fragment in this type of fracture However, *if one exposes the fracture site by a dorsal incision over* the Achilles tendon, skin necrosis sequestration and adherent tender scars may result as in group 1 b One should therefore endeavor to get by with a long cast or with percutaneously introduced screws or wires as in group 1 b (see p 2077)

Treatment of Fractures of the Medial Process of the Tuber Calcanei (Group 2)

The mechanism of fractures of the medial process of the tuber calcanei figs 2855 t, u, 2891, 2892) has been described on page 2048 Application of an Unna's paste boot is sometimes adequate for treatment If the pain is significant a lower leg walking cast *is applied for 3 weeks (see p 1928)* The patients can then immediately commence walking

If the fragment is markedly displaced as in figures 2914 and 2963 and produces pain on weight bearing it should be removed (fig 2913)

Treatment of Fractures of the Sustentaculum Tali (Group 3 a)

Fractures of the sustentaculum tali (fig 2690) are caused by falling on the supinated foot If no displacement is present, a short leg walking cast is applied If there is moderate or marked displacement, the fragment is pressed back into position with the heels of the thumbs or using the calcaneus com-





2914 July 24 1935 2915 January 25 1936

Fig 2914 —Fracture of the calcaneus group 2 with unusual displacemen of a fragmnt toward the sole It could be palpated and caused pain on walking

Fig 2915 —Same case after 6 months Because the projecting fragment caused symptoms on weight bearing it was removed Thereupon walking was painless

pression clamp under brief general anesthesia Thereupon a temporary lower leg cast is applied which is immediately split including the last thread (see p 1920) and after 4 to 5 days a lower leg walking cast is applied until the end of the sixth week after the injury (see p 1928) Then an Unna's paste boot is applied

Treatment of Fractures of the Anterior Portion of the Calcaneus (Group 3 b)

The mechanism of fractures of the anterior process of the calcaneus is described on page 2049 *Reduction* is not necessary *Immobilization* is achieved in temporary short bed cast (see pp 1920—1927) until the swelling recedes, that is 4 to 6 days Then a lower leg walking cast is applied (see pp 1928—1932) for an additional 3 weeks Then an Unna's paste boot is applied (see Verbandlehre/pp 70—84) The results are unusually good I have found persistent pain only in those patients in whom massage and passive movement were utilized without immobilization

Treatment of Fractures of the Calcaneus of Group 4

After every fracture of a bone a 1 to 3 mm portion of each fracture surface becomes necrotic and is readsorbed The fragments must therefore be

able to come together We must then strive to achieve a shortening of 1 to 10 mm and under no circumstances a lengthening This may appear surprising as we have up to now always attempted to prevent shortening

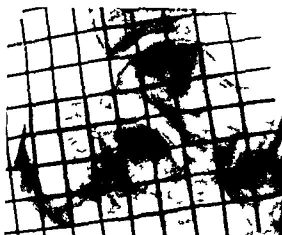
Lengthening of a bone by distraction of the fragments (dislocatio ad longitudinem cum elongatione aut distractione) is the most dangerous of all displacements, *because all of the disturbances described in Vol I/pp 26, 27 may thus* be produced



2918 October 9 1936 2919

Fig 2918 —Introduction of a Steinmann pin obliquely downward into the middle of the tuber calcanei

Fig 2919 —Reduction of the calcaneus fracture using the method of Westhues by depressing the pin and plantarflexing the forefoot



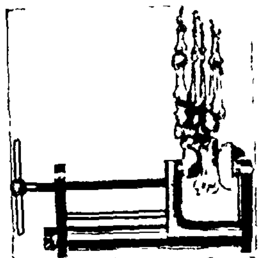
2919 a

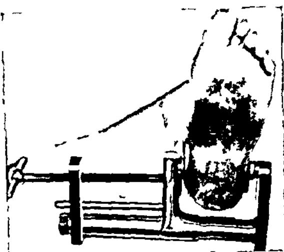
In order easily to determine the point of introduction of the transverse (frontal) pin for longitudinal traction and the sagittal pin (method of Westhues) a Jeschke wire grid (Vol II/figs 1696 1718) is fastened to the heel for the roentgenogram

For 40 years I have painstakingly avoided distraction in all other fractures Only for the calcaneus fractures have I used excessive weights for reduction and fixation As a result marked decalcification, hammer toes and pes cavus as well as marked limitation of motion often followed It was not until 1943 when we were studying callus formation (M N/pp 90—144) that we realized that the weights we were using for the reduction and during traction in

fractures of the calcaneus were excessive Since we have used small weights these disturbances have no longer appeared

The *mechanism* of fractures of the calcaneus group 4 is described on p 2149





2920 January 13 1929 2921

Figs 2920 2921 —After correction of the angulation on the screw traction apparatus the broadening of the calcaneus is corrected with the calcaneus compression clamp





2921 a August 18 1956 2921 b

Fig 2921 a —Shearing fracture of the tuber calcanei without involvement of the joint (group 4) Tuber joint angle 0° The tuber is displaced cranially The fracture cleft gapes caudally The transverse pin was placed just behind the fracture line rather than through the dorsocranial edge (elsewhere) Therefore it was not possible to replace the displaced fragment in spite of forceful traction

Fig 2921 b —Same case after removal of the pin The patient was admitted 10 days after the accident and the introduction of the pin The points of entry and exit of the pin were inflammed and painful The pin has migrated downward in the bone The hole left by the pin is twice as wide as the pin Tuber joint angle only 6°

In this group are included the entirely extra articular fractures at the posterior margin of the tuber calcanei (figs 2855 v, w and x), those that extend through its mid or anterior portion (figs 2921 a, 2921 b, 2947), as

well as the intra-articular compression fractures without displacement in the joint surface (figs 2893, 2949)

The fractures at the posterior margin without significant displacement (figs 2855 v, w) do not require reduction Those fractures with displacement that extend to the posterior margin of the talocalcaneal joint (figs 2855 x 2921 a, b, 2947) should be reduced and immobilized for an appropriate length of time because otherwise a painful arthrosis will develop at the posterior process of the talus (fig 2948)

Compression fractures without displacement (*figs 2893—2896*) *should* be slightly overcorrected and immobilized for an adequate length of time because otherwise they will sink together, as in fig 2950, and a painful arthrosis will develop If adequately treated, fractures of the calcaneus of group 4 have the best outlook for complete healing because the superior joint surface is not damaged

Of the three types of treatment (1) Conservative, i e, weight-bearing after 2 weeks, without reduction and without plaster immobilization or immobilization in plaster without reduction (2) Active, i e, reduction with a pain through the *calcaneus in the screw traction apparatus followed by continuous* traction or reduction with a sagittally placed nail according to Westhues and plaster immobilization with extreme muscle relaxation according to Wendt (3) Operative, i e, by exposure of the fracture and bolstering the superior joint surface according to Lenormant and Palmer, only reduction with the pin through the calcaneus and subsequent continuous traction for 8 to 10 days followed by plaster immobilization with extreme muscle relaxation comes under consideration (see pp 2083—2092)

The proponents of conservative treatment fear infection of the nail or wire track and arthrosis above all Infection can be avoided if (1) the nail or the wire is introduced at the correct point with the ankle dorsiflexed and not at the incorrect point as in figs 2921 a, b (2) a cast is not applied, so that the points of entry and exit of the pin remain visible, (3) no more than 3 kg is used for continuous traction, (4) the points of entry and exit are inspected daily and (5) the nail immediately removed when the slightest redness appears There is absolutely no danger of infection with the method of Wendt utilizing plaster immobilization with extreme muscle relaxation Arthrosis does not as a rule appear in group 4 fractures if the fracture is well reduced and is *continuously* immobilized until it is healed

Operative reduction does not come into consideration for this fracture because the superior joint surface and its support are not damaged

For reduction and immobilization of fractures of the calcaneus groups 4—8 the following materials are required in addition to those listed on page 1705 for the treatment of tibiofibular shaft fractures

1 A good lateral and an oblique plantar-dorsal roentgenogram (fig 2907) and appropriate exposures of the sound side for comparison *(see p 2066)*
2 A transparent ruler and protractor to measure the tuber-joint angle (Vol I/figs 91—54)
3 Local, general or spinal anesthesia (see Vol I/pp 118—121 and fig 152)
4 A Jeschke wire grid (Vol II/p 1243 and Vol II/figs 1696 2919 a)

5 A spring scale (Vol I/fig 139, figs 2942 a, b)
6 A quilted pad 0 5 × 10 × 18 cm (fig 2942 a)
7 A muslin bandage (fig 2942 a)
8 A compression clamp for the calcaneus (Vol I/fig 137, figs 2920, 2921)
9 Two pieces of felt 6 × 6 cm and 1 cm in thickness

Checking the Materials Listed on Pages 1705 and 2082 The bed, the Braun splint which has been wrapped and the remaining materials are rechecked in the manner indicated on page 1706

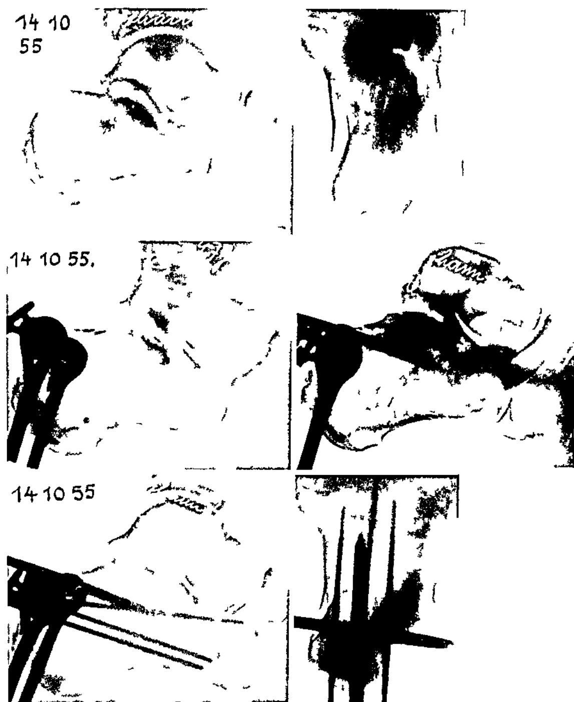
Selection of Patients Patients with tabes, severe diabetes, severe arteriosclerosis or with severe generalized diseases should not be subjected to reduction As a rule patients over 60 should also be excluded In these patients the broadened calcaneus should be pressed together under brief general anesthesia in order to achieve a better form of the foot The tuber-joint angle is reduced by this maneuver

Time of Reduction Formerly we placed the injured leg on a Braun splint for 6 to 10 days until the main swelling had receded Since 1939 we have reduced most of these fractures on the first day before a marked swelling has appeared because we have noted that exact reduction in comminuted fractures of the upper and lower end of the tibia for example as well as the posterior fracture dislocation of the ankle with the large posterior wedge is only possible in the first day At this time it is usually possible to replace the fragments exactly

If it has not been possible for some reason to carry out reduction on the first day, one must wait until the swelling has disappeared or the blebs have dried In order to shorten the waiting period the swelling can be pressed away with sponge rubber or steel wool beginning the third day The bandages should not be so tight as to produce pain When the fragments have become adherent to one another after two weeks or more, one should not attempt to reduce them by forceful traction as they will remain fixed The joints will be pulled apart and damaged In these cases one should loosen the tuber calcanei with the padded calcaneus compression clamp Then it is possible even in fractures that are no longer fresh to restore the form of the foot in continuous traction or with the sagittal nail according to Westhues

Use of the Jeschke Grid for the Lateral Roentgenogram The pin or wire should be introduced just anterior to the dorsal-cranial edge of the tuber calcanei In order to determine exactly the point of introduction a wire grid is placed on the medial side of the tuber calcaneus and fastened in such a manner that the protruding ends but not the crossings are covered, because otherwise they cannot be properly counted The lateral roentgenogram is then made The point of introduction of the nail or the wire can be accurately determined from this roentgenogram In the roentgenogram in figure 2919 for example this point is in the middle of the fourth square from below and the seventh from in front This point is marked by pressure with a forceps

It is important to place the pin or wire accurately If it is introduced more ventrally as for the treatment of a lower leg shaft fracture it is not possible to exert a lever action and if it is in the fracture cleft, it will begin to



2922—2927 October 14 1955

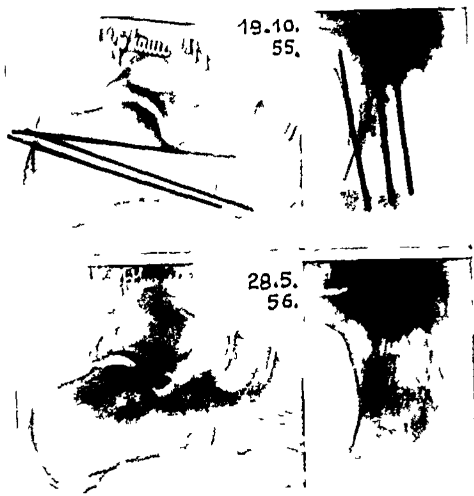
FIGS 2922 2923 above—Left fracture of the calcaneus group 5 Sustained in a fall over a stair by a 47 year old laborer who weighed 67 Kg and was 165 cm tall The calcaneus is broadened to 46 mm is shortened and somewhat adducted The lateral wall is sheared off and the sustentaculum tali broken off in the typical manner In the lateral view the superior joint surface is seen to be displaced somewhat downward the fracture being behind the joint Tuber joint angle 0^0

FIG 2924 middle left—Same case The talocalcaneal joint has been distracted to 9 mm with 6 Kg longitudinal traction The tuber joint angle has been improved by only 5^0

FIG 2925 middle right—It was possible to lift the superior joint surface of the calcaneus by the introduction of a sagittal pin into the fracture cleft from craniodorsal The tuber joint angle is 30^0

FIGS 2926 2927—Same case In order to maintain the reduction three longitudinal Kirschner wires were introduced The calcaneus is still broadened We no longer use this type of fixation for these fractures

migrate solewards in continuous traction (fig 2921 b) exerts pressure and causes necrosis, which in turn leads to infection of the fracture if it is not removed in time The point of introduction of the sagittal pin can also be determined from the roentgenogram made with the Jeschke grid



2930 2931, May 28 1956

FIG 2928 2929 above—Same case after 5 days The two pins were removed immediately after reduction The three wires are in the calcaneus Position in both planes is good The broadening and adduction have disappeared because the calcaneus has been compressed with the calcaneus compression clamp

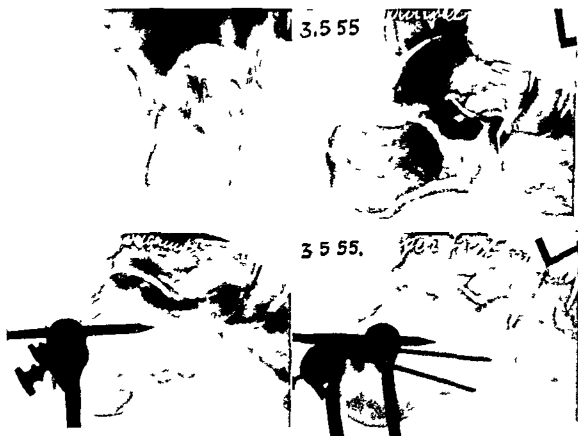
FIGS 2930 2931—Same case after 7 5 months Good form of the calcaneus in both planes The wires were removed after 16 weeks No significant decalcification The joint space between talus and calcaneus of normal width Wore a walking cast for 10 weeks Pronation and supination restricted 50% All other joints freely mobile Form and color of the foot normal Resumed his work after 6 months Some pain on strenuous exertion

Anesthesia If displacement is minimal, local anesthesia is adequate Otherwise spinal or general anesthesia may be used

Introduction of the Pin with a Hammer or of the Wire with a Drill We prefer to use a pin rather than a wire because it is more firmly fixed in the bone For placement of the sterile pin the foot must be markedly dorsiflexed or the skin will be pulled taut by the traction and may tear if large weights are used

If the skin is pulled in on the medial side by the nail or is tented up on the lateral side it must be flattened by finger pressure The points of entry and exit of the nail are left uncovered

Placement of the Rotating Stirrup and the Cap for the Point of the Pin After the placement of the nail when the skin has been flattened it is provided



2932—2935

FIGS 2932 2933 above —Fracture of the left calcaneus group 6 Sustained in a jump from a 6 M height by a gas company employee who was 164 cm tall and weighed 68 Kg Simultaneous fracture of the right calcaneus group 5 The calcaneus is broadened to 50 mm and shortened The lateral wall is broken out and the sustentaculum tali is broken off in the typical manner In the lateral view the entire posterior joint surface can be seen to be drepressed and tipped plantarwards There is a gap of 10 mm between the posterior joint surfaces of the talus and the calcaneus The tuber joint angle is 10°

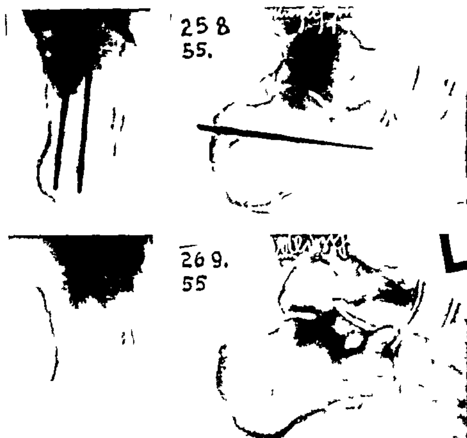
FIG 2934 left below —Same case during reduction The calcaneus has been reduced by traction on a frontally placed pin and by leverage on a sagittally placed pin

FIG 2935 right below Same case after introduction of two wires which are located too far plantarward Therefore two others were inserted The tuber joint angle is 30° 5 weeks after injury bilateral lower leg walking casts applied which were removed 5 weeks later

with a rotating stirrup (Vol I/figs 127, 128) The stirrup must be of the rotating type because usually traction is applied in two different directions If the stirrup is firmly fastened to the nail so that rotation is not possible, traction in two different directions would be possible only if the nail could turn in relation to the bone and this could lead to a loosening of the nail and to infection of the nail site The screws should be so applied that their

heads point dorsally so that the fracture sites are not covered Then the point of the nail is covered with the metal cap

Placement of the Leg for Reduction After the introduction of the nail, the application of the rotating stirrup and the cap for the nail the leg is placed on the screw traction apparatus and is suspended from its U-support by means of the calico bandage which is padded with the 0 5 × 10 × 18 cm



2936—2939

Figs 2936 2937 above Same case after 4 months Both of the newly placed wires in good position In the lateral view they are superimposed The two Steinmann pins were removed after the introduction of the wires No decalcification

Figs 2938 2939 below – Same case after 5 months The wires have been removed The position of the fragments is good The broadening has disappeared The joint between the talus and the calcaneus is reduced The joint space is regular The tuber joint angle has decreased to 10° because the patient began weight bearing too soon Resumed his occupation after 6 months At reexamination after 13 months the toes on both sides are freely movable The mobility of the talocalcaneal joint is restricted only at its extreme ranges Mobility at the ankle is 80° to 125° on the left as compared to 75° to 120° on the right Skin color normal no significant swelling able to walk on tip toe and on his heels No significant complaints Works in his forme occupation

quilted pad Traction can thus be exerted in an oblique direction, namely in the longitudinal axis of the calcaneus (fig 2909) when the rotating stirrup has been fixed to a spring scale and this in turn fixed to the hook of the screw which is placed as low as possible (fig 2942 a) Formerly we used a pin through the leg behind the tibia or through the lower metaphysis of the tibia



December 12 1928

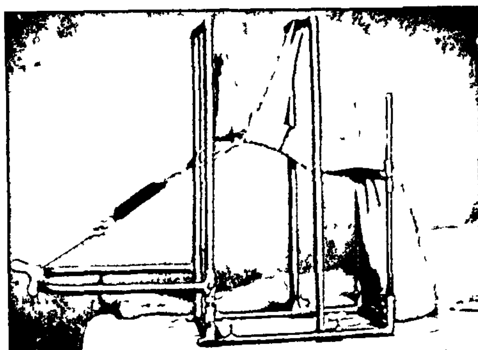
Fig 2941 —Preparation of the screw traction apparatus for reduction of fractures of the calcaneus A Steinmann pin is driven through the tibia above the ankle joint The leg is held up by this The second pin through the posterior upper edge of the tuber calcanei serves a fixation point for the oblique downward traction in the longitudinal axis of the calcaneus A spring scale is interposed between the hook of the screw traction apparatus and the rotating stirrup Since 1935 we use a well padded sling for suspension of the leg as in fig 2942 a rather than the pin through the tibia



September 25 1930

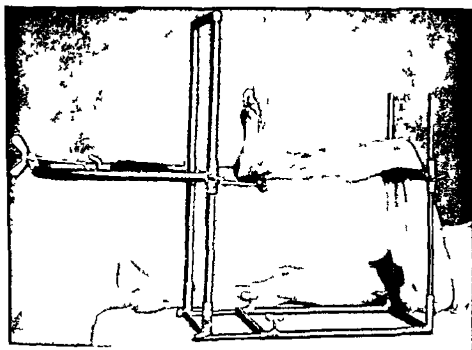
Fig 2942 —Plantar flexion and pronation of the forefoot with simultaneous dorsiflexion of the great toe for reduction of a fracture of the calcaneus In this position a good longitudinal and a good transverse arch are produced The same movements of the foot can also be carried out if the lower leg is suspended by a padded sling rather than a pin or a wire through the tibia as in fig 1942 a

for countertraction (figs 2941, 2942) The well padded muslin bandage serves the same purpose as the pin through the lower end of the tibia and is without hazard in contradistinction to the pin, as neither shattering of the tibia nor infection can result from its use



August 8, 1938

Fig 2942 a —Positioning of the leg for reduction of fractures of the calcaneus In order to exert longitudinal traction in the axis of the calcaneus the lower leg is suspended by a strong well padded sling The pin is placed in the posterior upper edge of the tuber calcanei The patient is in a plaster jacket because of a simultaneous vertebral fracture



August 9 1938

Fig 2942 b —After the shortening and the angulation have been corrected by longitudinal traction in the axis of the calcaneus namely obliquely downward longitudinal traction is exerted in the axis of the tibia in order to still further increase the tuber joint angle The sling for suspension of the lower leg should not be removed for this maneuver

Reduction of the Fracture Traction of 5 to 6 Kg is then exerted in this position At the same time the forefoot is plantarflexed and pronated (fig 2942) The shortening, the angulation with the medially and cranially open angle and in part the parallel cranial displacement are thus corrected The broadening is reduced In groups 5—8 the talus is pulled out of the calcaneus and the joint between both bones is restored Formerly we used traction of 20 Kg even in fresh fractures because it was often necessary in 1 to 3 week old fractures In fresh fractures excessive traction leads to distraction with all the undesirable complications listed in Vol I/pp 26, 27

Thereupon the traction is released The horizontal U-support with the screw of the screw traction apparatus is raised until the leg is horizontal Then 5 to at the most 10 Kg traction is exerted in the longitudinal axis of the lower leg thus restoring the tuber-joint angle of 35° to 40° If this is not achieved by longitudinal traction alone, the tuber is reduced with the sagittally introduced pin according to the method of Westhues (figs 2918, 2919 2926, 2934)

Overcorrection of the Tuber-joint Angle The tuber-joint angle should always be about 5° greater than on the uninjured side, in order that the cranial edge of the fracture for example of figure 2921 b or 2947 is pulled away from the area of the posterior process of the talus in order to avoid the development of an arthrosis there

Roentgen Check New roentgenograms are made from both sides after reduction If the tuber-joint angle is not overcorrected by 5° the longitudinal traction is increased by 1 to 3 Kg until a new roentgenogram shows that the displaced fragments are in satisfactory position

Immobilization in Continuous Traction on the Braun Splint When the lateral roentgenogram shows good position, the leg is placed on a Braun splint while light traction is exerted on the rotating stirrup and 5 Kg traction then applied Both ends of the nail are suspended as in figure 2378 c in order to guard against rotation The lower end of the bed is elevated 30 cm as for a tibiofibular fracture (fig 2374) We formerly applied a temporary lower leg cast and applied 5 Kg traction The cast is superfluous Furthermore it has the disadvantage of covering the points of entry and exit of the pin Since 1939 we have no longer used the cast but continued the use of 5 Kg traction This led to pes calcaneus (hook foot) and to distraction with its undesirable complications At present we do not use a cast after reduction The points of entry and exit of the pin remain exposed so that they can be inspected at any time When redness appears about the pin it must be immediately removed in order to avoid infection

Exercises The toes should be actively moved through their full range daily

Roentgen Check After two days new roentgenograms are made in both planes to determine whether the good position has been maintained

Removal of the Pin and Application of a Mid Thigh Cast with the Foot in Plantarflexion and the Knee at a Right Angle If the cast is applied in this position, the gastrocnemius is relaxed because the origin and the insertion

are brought 10 cm closer together (Vol I/figs 1—6) It is thus usually possible to maintain the fragments in good position

The following materials are required for removal of the pin, application of the cast and maintaining the position of the leg

1 A table for the patient (fig 2942 a)
2 A screw traction apparatus from which the peripheral portion has been removed so that only the horizontal frame and the knee support remain (fig 2942 c)
3 An instrument table for the materials listed under points 4 to 15 for the removal of the pin
4 Two sterile thumb forceps
5 Four or five sterile 4 × 4 cm sponges 8 layers thick
6 Two sterile 2 × 2 cm sponges 8 layers thick
7 One sterile 6 × 12 cm sponge 8 layers thick
8 Benzene
9 Alcohol
10 Balsam of Peru
11 Heavy pliers (Vol II/fig 1690)
12 Skin adherent
13 Sterile cotton tipped applicators (Vol I/fig 152)
14 A 5 × 30 cm flannel strip (fig 2175)
15 A 5 × 70 cm flannel strip (fig 2175)
16 Plaster shears
17 Light 17-thread plaster rolls 15 cm wide, 5 M long weighing 400 Gm
18 A 'calcaneus splint' for support of the plaster immobilized leg
19 or a frame and a wide band to support the leg and right angle cast similar to the manner shown in figure 2350 a

Placement of the Leg on the Knee Portion of the Screw Traction Apparatus When the swelling of the ankle has receded after about 8 to 10 days the patient is premedicated with Pantopon, Trial or other pain-relieving drugs and the foot is brought into extreme plantar flexion and the traction weights removed The leg is placed on the knee portion of the screw traction apparatus with the knee at a right angle The foot and lower leg must be held continuously in this position by an assistant, until the cast has been applied

Removal of the Calcaneus Pin The pin is removed in the manner described on page 1724

Placement of a Large Sponge on the Heel and the Achilles Tendon In order to keep the skin clean for a possible subsequent operation the 6 × 12 cm sterile sponge of eight thicknesses is placed on the Achilles tendon after two thin lateral strokes of skin adherent have been applied

Application of the Lower Leg Cast The 5 × 30 cm flannel strip is placed below the knee joint as described on page 1920, with the difference that the flannel is not turned down, and the cast is not split

Roentgen Check As soon as the lower leg cast has been applied a plantar-dorsal and a lateral roentgenogram are made

Application of the Long Cast When the roentgenograms show good position the cast is lengthened to the upper third of the thigh The screw traction apparatus is removed and the lower leg is suspended by a wide band from a frame that has been placed over the operating table or from a hook in the ceiling in a manner similar to that shown in figure 2350 a, but so that the right angle at the knee is continuously maintained Then a few strokes of skin adherent are applied to the upper third of the thigh The 5 × 10 cm strip of flannel is placed so that its two ends cross laterally Folds should be avoided A 50 cm splint is made from a plaster roll and is applied from the middle of the lower leg extending across the popliteal space to the middle of the flannel strip and is smoothed on A circular plaster bandage is applied over this Then a second 50 cm splint is placed on the anterior surface of the leg extending from the middle of the lower leg over the knee to the upper third of the thigh Two circular plaster rolls are applied over this

Placement of the Leg When the cast is hard the leg is placed on the calcaneus splint or is suspended from a frame by a wide band in a manner similar to that shown in figure 2350 a but without a splint

Cleaning of the Toes and Inscription of the Cast is carried out as described on pages 1922—1926

Exercises The toes should be actively extended beginning the first day If the patient has no pain he can get up with crutches He may not bear weight on the leg In order that he can more easily maintain the horizontal position of the lower leg, a sling is placed around the ankle joint and is fastened over the opposite shoulder

Roentgen Check A plantar-dorsal and a lateral roentgenogram are made 5 to 6 weeks after the injury

Shortening of the Long Leg Cast If the roentgenograms show significant displacement arthrodesis of the talocalcaneal joint is carried out (see p 2098) If they show good position the thigh and knee portions of the cast are removed The leg is placed on a Braun splint for two days and then on an oblique splint with the knee in extension

Roentgen Check Four days after shortening of the cast a plantar-dorsal and a lateral roentgenogram are made

Application of a Short Leg Walking Cast When the roentgenograms show good position the short leg cast is removed Then with the knee at a right angle the foot is carefully dorsiflexed to 100° to 110° and a short leg walking cast is applied for 4 weeks in the manner described on page 1928

Roentgen Check After the application of the short leg walking cast a plantar-dorsal and a lateral roentgenogram are made

Application of the Walking Stirrup and Exercise When the roentgenograms show good position a walking stirrup is applied (see p 1928) and exercises are carried out in the manner described on page 1928

Removal of the cast roentgen check application of the Unna's paste dressing exercises and the making of the arch supports are carried out in the manner described on pages 1930 and 1931

Results of Treatment in Group 4 Fractures If reduction has been successful and the position of the fragments is maintained until union has occurred, a painless movable joint usually results If displacements have occurred late the joint should be made painless by an arthrodesis

Treatment of Fractures of the Calcaneus of Groups 5—8

The *mechanism* of these fractures is described on pages 2049

Treatment If none of the contraindications listed on page 2083 are present, these fractures should be reduced in order to achieve a normal form of the foot, since symptoms result not only from the post traumatic arthrosis of the talocalcaneal joint but also from the broadening of the heel and the diminution of the tuber-joint angle as well as from the varus or valgus position Painful arthroses of the lateral malleolus with interference of gliding of the peroneus tendons result from the broadening of the heel Flat-foot and rapid fatigability result from the broadening of the heel Pain on walking results from pronounced varus because some of the patients step only on the outer margin of their foot and from pronounced valgus because some patients step only on the inner margin of their foot Sometimes spastic flat-foot results from the pain (see p 2109) In the presence of malposition pain may persist in spite of arthrodesis of the talocalcaneal and talonavicular joints At the same time however, there are patients who are painfree in spite of malposition Infection can usually be avoided by conscientious observation of the points of entry and exit of the pin, early removal of the pin with application of the cast or completely avoided by reduction with extreme muscle relaxation according to the method of Wendt

For *reduction and immobilization* the same materials are required as listed for fractures of the calcaneus group 4 (see p 2082)

Study of the roentgenograms must be painstaking in order to determine to what group the fracture belongs, how badly disrupted the superior joint surface is and how large the tuber-joint angle is on the sound side as well as on the injured side Not only the point of introduction of the transverse (frontal) pin but also in the case of displacement of the superior joint surface the point of introduction of the posterior (sagittal) nail as well as its direction must be determined from the lateral roentgenogram with the Jeschke grid (fig 2919 a)

Time of reduction The same applies here as for fractures of the calcaneus group 4 (see p 2083)

Introduction of the pin, placement on the screw traction apparatus and reduction are carried out in the same manner as for fractures of the calcaneus group 4 (see pp 2085—2089)

Restoration of the Superior Joint Surface of the Calcaneus in Fractures of Group 5 If in group 5 the entire superior joint surface or its lateral portion has been driven into the spongiosa of the body of the calcaneus and cannot be restored by traction (fig 2924), it can be lifted by a pin driven in from dorsal-cranial according to the method of Westhues (fig 2926)

Restoration of the Superior Joint Surface of the Calcaneus in Fractures of Group 6 (figs 2932, 2933) In these fractures it is never possible to restore the superior joint surface of the calcaneus in the screw traction apparatus The gap between the posterior fragments is as a rule increased by traction The restoration is easily accomplished with a sagittally introduced pin (fig 2934) When necessary it should be introduced parallel to the cranial surface of the tuber calcanei even before the placement of the transverse pin

Roentgen Check After reduction a plantar-dorsal and a lateral roentgenogram should be made





2942 c 2942 d

Fig 2942 c—Reduction of a fracture of the calcaneus in the presence of extreme muscle relaxation according to the method of Wendt The knee joint is raised by means of a vertebra sling which has been lubricated and encased in oilcloth until the buttock of the involved side clears the table An acute angle is thus produced at the knee The foot is then maximally plantar flexed The calcaneus compression clamp is applied over felt pads Traction in the axis of the calcaneus is exerted with it as in fig 2942 a

Fig 2942 d—The traction on the calcaneus clamp is exerted somewhat behind the axis of the tibia similar to the manner shown in fig 2942 b Both illustrations are from a publication by Wendt

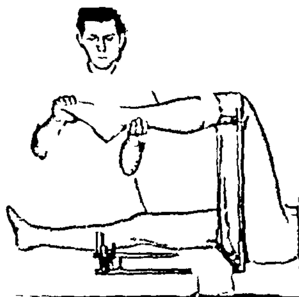
Correction of the Broadening of the Calcaneus This may not be carried out until the superior joint surface of the calcaneus has been restored The heels of the thumbs or better the calcaneus compression clamp may be used for this purpose This is applied with the straight aluminum pad on the outer side and the concave aluminum pad on the inner side below the sustentaculum tali (figs 2920, 2921) This is closed until the distance between the aluminum pads is 35 mm *The clamp must immediately be opened and removed in order to prevent damage to the skin from pressure* This must be particularly stressed because when this warning has not been heeded pressure damage has been described We have never seen damage from pressure due to use of this instrument even though we have used *it in many hundreds of cases*

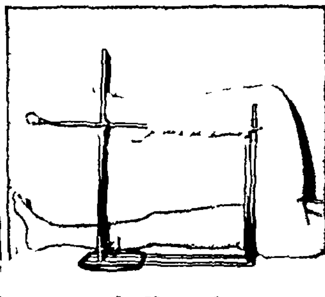
Roentgen Check New roentgenograms should be made after the compression

Immobilization in traction or the Braun splint is carried out for 8 to 10 days in the same manner as in fractures of the calcaneus group 4 (see p 2046)

Immobilization with Percutaneously Introduced Wires In 1955 and 1956 we introduced two to three wires percutaneously in 19 cases for immobilization in order to maintain the reduced position without continuous traction (figs 2926—2929 and 2934—2937) Since it is difficult to place them correctly and since in 3 cases minimal drainage occurred, we have discarded this method I have however presented it in order to advise against its use

Removal of the pin and application of the long leg cast with the foot in plantarflexion and the knee at a right angle is carried out after the swelling





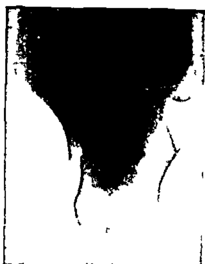
2942 e 2942 f

Fig 2942 e —Positioning of the leg for application of a long leg cast 8 to 10 days after reduction in a fracture of the calcaneus The knee rests on the knee portion of the screw traction apparatus in right angle flexion The foot is maximally plantar flexed The 6×15 cm sterile sponge is fastened over the heel and the Achilles tendon to protect the skin The flannel strip is placed around the leg below the knee joint

Fig 2942 f —Positioning of the leg on the so called calcaneus splint after application of the long leg cast This splint was constructed in 1947 for use in continuous traction in fractures of the calcaneus The leg can also be suspended by a sling as in fig 2350 a

recedes in 8 to 10 days in the same manner as for fractures of group 4 (see pp 2091 2092)

Reduction and Immobilization of Fractures of the Calcaneus Groups 5—8 with Extreme Muscle Relaxation according to Wendt (see p 2070 below) In order to avoid any possibility of infection from pin or wire traction the method in which the knee and the ankle are markedly flexed was recommended by Wendt We utilized this principle already in 1921 (see p 2070) What is new is that he encloses the entire leg in a cast in this position He states, With the patient in deep anesthesia the knee is suspended by a well lubricated girth that is encased in oil cloth and attached to a stirrup as used for reduction of vertebra fractures The stirrup is raised until the thigh is almost vertical and the buttock of the injured side has cleared the table and





2943 June 12 1928 2944

FIG 2943—Fracture of the calcaneus with widening dorso plantar exposure The lateral wall is broken and protrudes The sustentaculum tali projects medially The calcaneus is shortened

FIG 2944—Lateral view to fig 2943 The body of the talus has been driven deeply into the body of the calcaneus The angle between the superior joint surface of the calcaneus and its posterior process has disappeared (group 5)





2945 December 8 1928 2946 June 12 1928

FIG 2945—Same case The calcaneus is again of normal length and width

FIG 2946—Same case The posterior joint space between talus and calcaneus is now of normal width The angle between the superior joint surface of the calcaneus and the tuber calcanei has been restored and is 30°

the lower leg hangs down The calcaneus compression clamp is now applied in the usual manner and the broadening of the calcaneus corrected by tightening of the clamp While the foot is maintained in plantarflexion with one hand the other using the cross-piece of the calcaneus clamp as handle



2947 June 3 1933



2948 May 4 193"

Fig 2947 —Three week old shearing fracture of the tuber calcanei in a 18 year old apprentice The tuber calcanei is displaced cranially without significant angulation Reduction was no longer possible because the fracture was already 3 weeks old If the tuber calcanei had been mobilized with the calcaneus compression clamp reduction probably would have been successful

Fig 2948 —Same case after 4 years Because the fracture could no longer be reduced severe arthrosis developed not only in the talocalcaneal joint but also in the talonavicular joint Rotation of the forefoo markedly limited Pain on walking especially over uneven ground An arthrodesis should be carried out in this case



2949 September 21 1935



2950 March 31 1936

Fig 2949 Relatively mild fracture of the calcaneus group 4 Because of the age of 64 and because of bladder problems the fracture was not reduced

Fig 2950 —Same case after 6 months The tuber calcanei is displaced cranially Marked decalcification even though reduction was not carried out

first pulls in the direction of the longitudinal axis of the calcaneus (fig 2942 c) and then in a plantar direction (fig 2942 d) In this manner the shortening of the calcaneus is thus corrected first and then the tuber-joint angle is restored From this point on the plantarflexion must be continuously maintained until the cast is completed The removal of the compression clamp is followed by fluoroscopy that usually shows complete reduction If the plantarflexion is lessened for a moment, one can observe how the tuber joint angle immediately becomes smaller, an occurrence which is easily reversible by completely plantarflexion the foot with one hand and grasping the tuber calcaneus between the thumb and forefinger of the other and

forcing it downward The position achieved is maintained as long as the plantarflexion is maintained It is also maintained if plantarflexion is unchanged and the knee is slowly extended to a right angle A long leg cast is now applied with the knee at a right angle and the foot in extreme plantar flexion The cast must be carefully molded to the plantar arch and to the contours of the calcaneus Then the entire cast is split longitudinally on the anterior aspect and the girth used for suspension of the knee that has been enclosed by the cast is removed With this cast we were able to maintain the reduction achieved The question was whether exceptionally in the case of calcaneus fractures it was allowable to break the otherwise basic rule that immobilization in plantar flexion must be avoided It seemed however that there was enough leeway in the long period of treatment that was required in fractures of the calcaneus under any circumstances to correct stepwise the extreme position chosen in the beginning by appropriate plaster immobilization until the normal position was reached The long leg cast described above is followed in 6 weeks by a cast applied under anesthesia with the knee at 30° flexion and the ankle in mild plantarflexion After an additional 4 weeks the third long leg cast is applied in normal position Finally a short leg walking cast is applied for an additional 4 weeks

Shortening of the Long Leg Cast and Application of a Short Leg Walking Cast If the good position has been maintained by the long leg cast with the knee at a right angle and the foot in plantarflexion, further treatment is carried out by shortening the long leg cast and applying a short leg walking cast in the same manner as for fractures of the calcaneus group 4 (see p 2092) The short leg walking cast however is maintained for 6 weeks rather than 4

Early Arthrodesis of the Talocalcaneal Joint

In fractures of groups 4—8 if the joint surfaces are so comminuted that reduction is impossible, or when exact reduction has not been achieved, or when subsequent redisplacement occurred, it is expedient to carry out an early arthrodesis in order to shorten the time of treatment and rapidly achieve a painless useful foot Van Stockum [1] of Holland in 1911 was the first to recommend arthrodesis without prior reduction in fractures of the calcaneus The Americans were next, namely Reich 1926 and Wilson [3] who already reported 18 cases in 1927 Since that time arthrodesis without previous reduction has become widespread in America In German speaking countries it is seldom used as can be seen from the review by Kerstner (see p 2068 footnote) As early as 1938 I recommended arthrodesis in old fractures in the 5th edition of this book Lange [4] described it fully in his book in 1951 after

1 Van Stockum Traitement sanglant des fractures fermees du calcaneum Congres francais de chir 24 801

Reich R Subastragaloid arthrodesis in the treatment of old fractures of the calcaneus Surg Gynec Obst 42 420—422 1926

3 Wilson P O Treatment of fractures of the os calcis by arthrodesis of the subastragalar joint J A M A *89* 1676

4 Lange M Orthop chir Operationslehre Munchen Bergmann Verlag 1951

he had recommended it for painful flatfoot as early as 1932 Early arthrodesis after previous reduction was recommended in 1951 by Ehalt (see p 2073 footnote) and also by Becker[5] and in 1953 by Schumpelick[6] In the German speaking countries Ehalt is the foremost proponent of early arthrodesis after prior reduction In 1956 he published 67 operations in fractures of the calcaneus in 59 patients, the largest number up to now Of these 58 operations in 50 patients have been subsequently reexamined Russe[7] presented his method pictorially in 1955

In all cases in which an arthrosis of the talocalcaneal joint is anticipated an early arthrodesis should be carried out, because many patients will not accept an arthrodesis later because they will be unable to work for several months, and some also fear that they might lose their disability pension, if their condition improves A good result can be achieved by early arthrodesis without prolonging the treatment

The following materials are necessary for carrying out early arthrodesis of the talocalcaneal joint

1 A rapid developer (see Vol II/p 1253)
2 Sterile pillow cases for the film cassettes for the lateral roentgenograms during the operation
3 The usual instruments for a surgical operation such as knives, scissors, thumb forceps, hemostats retractors needles, needle holders, etc
4 Sharp straight chisels (Vol II/fig 1689)
5 A hammer (Vol II/fig 1686)
6 A cylindrical saw according to Scherbichler 18 mm in diameter (figs 2765 to 2767)
7 Several hard smooth guide wires 2 2 mm thick and 22 cm long (figs 1678, 1681, 1691)
8 A pneumatic bone drill (Desoutter) with wire guide frame (fig 1696)
9 Or an electric drill with wire guide frame (fig 1699)
10 A steel cylinder with compressed air
11 A cannulated drill 8 mm in diameter for the cortical bone (fig 1678)
12 A double set of cannulated three-flanged nails with threaded holes countersunk in their heads — according to Smith-Petersen and Sven Johansson 6 to 8 cm long
13 A metal ruler (Vol II/fig 1693)
14 A centrally cannulated driver for driving the nail (Vol II/fig 1684)
15 Heavy pliers for removing the guide wire (Vol II/fig 1690)
16 A 7 5 cm device for extracting the nail (Vol II/figs 1678, 1679)
17 A strong hook 3 5 mm in diameter to attach to the extracting device according to Kuntscher and Pohl (Vol II/fig 1674)
18 A slotted hammer according to Pohl and Kuntscher to drive the nail out by means of the hook (Vol II/fig 1679)

[5] Becker F Primare Arthrodese bei der Behandlung von Fersenbeinbruchen Zentralbl f Chir 76 831—837 1951

[6] Schumpelick W Die Behandlung schwerer Fersenbeinbruche durch fruhzeitige Span arthrodese Arch orthop u Unfall Chirurg 46 66—77 1953

[7] Russe O Atlas of Operations for Trauma Vienna Maudrich 1955

Application of the Tourniquet and Positioning of the Patient After suitable preparation of the skin the tourniquet is applied Then the patient is turned face down

Exposure of the Talocalcaneal Joint and Creation of the Rotation Bolt The joint is exposed in the manner described by Gallie[1] by means of an incision lateral to the Achilles tendon The fatty tissue is partly removed The joint capsule is incised The lateral tubercle of the posterior process of the talus is removed with a chisel In this manner a good view of the talocalcaneal joint is obtained The blade of the Scherbichler instrument is driven 3 cm into the joint space When the roentgenograms in the two chief planes show that the instrument is well placed a cylinder is sawed out of the two bones that make up the joint Then the blade and thus also the two half cylinders are rotated 90° After the cylindrical saw is removed the bone cartilage cylinder is impacted with the driver The resulting hole on the dorsal side is then filled with bone chips which have been obtained from the lateral tubercle of the posterior process and been cut up

Placement of the Guide Wire and Driving the Three-flanged Nail The 2 2 mm thick and 22 cm long guide wire is inserted percutaneously through the calcaneus into the head or the neck of the talus (fig 2962 b) from lateral-caudal to medial-cranial When roentgenograms in both major planes show it to be in good position, the bone is exposed through an approximately 5 cm transverse incision along the wire A hole 6 to 8 cm deep is drilled into the cortical bone with the cannulated drill The length of the wire from the surface of the calcaneus to the surface of the talus is accurately measured Then the appropriate three-flanged nail is driven over the guide wire The head of the nail should be driven flush with the bone In figure 2962 a it projects too far The joint is stabilized in this manner When the roentgenograms in both chief projections show that the nail is in good position the skin is closed, a pressure dressing is applied, the tourniquet is removed and the leg is placed on a Braun splint

If the nail is too short or too long, it is removed with the extracting device (Vol II/figs 1678, 1679) and exchanged

As soon as we can use fluoroscopy with image intensification the introduction of the steel blade and the guide wire will be simpler

If the wound heals without complication an Unna s paste dressing can be applied after two weeks and the patient may then get up In the presence of severe pain a short leg walking cast may be applied for 2 or 3 weeks

The use of the three-flanged nail has the advantage that immobilization in a cast usually requiring 4 months is no longer necessary Ankylosis of the joint usually results after 3 to 4 months The nail can be removed after a year

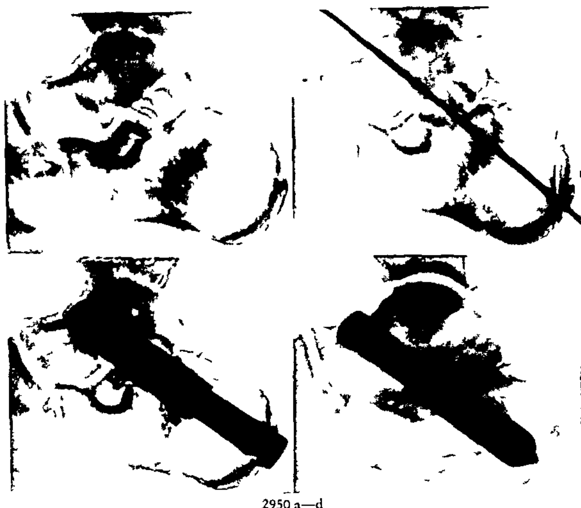
As a rule arthrodesis of the talocalcaneal joint is sufficient It is not necessary to fuse the joint between the calcaneus and the cuboid unless the anterior process of the calcaneus is comminuted

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1 Gallie Bone Surg 1942

Late Arthrodesis of the Talocalcaneal Joint

If a painful arthrosis develops in the talocalcaneal joint after a fracture of the calcaneus, it should be treated using the same technique as for early arthrodesis If the tuber-joint angle is decreased an appropriate bone wedge



2950 a—d

Fig 2950 a—*Three month old fracture of the calcaneus that has healed by bony union with* irregular joint and pain The joint was exposed by a curved lateral incision under the lateral malleolus and two rotation bolts (fig 2867/4) were used to achieve an arthrodesis using the Scherbichler instrument (figs 2765—2767)

Fig 2950 b—*Same case after the introduction of the guide wire*

Fig 2950 c—Same case after the driving of the three flanged nail from posterior below to anterior above The patient was able to walk without a cast in an Unna s paste dressing 3 weeks after operation

Fig 2950 d—Fracture of the calcaneus treated by Ehalt with a wedge arthrodesis and a three flanged nail which was driven from above anteriorly to below posteriorly through the calcaneus Bony union was complete in 4 months

from the tibia, the iliac crest or the bone bank is inserted dorsally or in the presence of varus or valgus medially or laterally Then the three-flanged nail is driven in from posteriorly In the presence of accompanying arthroses in the joints between the calcaneus and cuboid or between talus and navicular these joints are also fused with rotation bolt arthrodeses

The presence of circulatory disturbances on an arteriosclerotic basis with absence of the dorsalis pedis and the posterior tibial pulses, with cyanosis of the foot that appears on standing or the presence of intermittent claudication contraindicates the operation



2951 February 3 1934 2952

Figs 2951 2952—*Open* fracture of the calcaneus sustained by a 52 year old woman in a one story fall Simultaneous dorsal dislocation of the foot in Chopart s joint The lower leg with the talus has been forced downward between the tuber calcanei and the navicular The navicular and the calcaneus are at the level of the lower end of the tibia Then reduction in the screw traction apparatus Simultaneous fracture of the first lumbar vertebra

Decalcification Following Fractures of the Calcaneus

Formerly we often encountered more or less severe decalcification of all bones of the base of the foot after many fractures of the calcaneus It was more severe in the older age groups and with the more severe fractures It was especially severe in those patients treated with the two pins and plaster fixation It was not until 1943 that I realized that excessive traction during reduction and further care was the cause, although I had long been aware of this for all other fractures Since we have used no more than 5 to 6 Kg as a rule and never more than 10 Kg for reduction and never more than 3 Kg for continuous traction, these severe decalcifications are no longer encountered

These decalcifications are often treated with measures that are supposed to lead to callus formation or recalcification as they are listed for the treatment of delayed callus formation and pseudarthrosis in Vol I/pp 242—249 Treatment with such medicaments is superfluous since the calcium content is restored when the muscle atrophy disappears as the result of appropriate use of the leg and the circulation is improved Those who inject so-called recalcification promoting medications vitamins and hormones wrongly assume that the decalcification disappears as a result of these remedies, because they do not know that these measures are without effect and that the calcium

content is spontaneously restored after a corresponding length of time by the natural use of the foot

Decalcification can also occur in those cases in which reduction has not been carried out (fig 2950) Weight bearing is painful as long as the decalcification persists

Orthopedic Braces for the Treatment of Old Fractures of the Calcaneus

Formerly I often saw patients after fractures of the calcaneus who in addition to callus forming medications, irradiation of all sorts also have been given braces which support the leg at the head of the tibia or at the ischial



2953 October 1 1937 2954

Figs 2953 2954 Same case after 3½ years Calcaneus healed without wound complication in good position with shortening Dislocation in Chopart s joint reduced Bony ankylosis between talus and calcaneus Pain only on prolonged walking

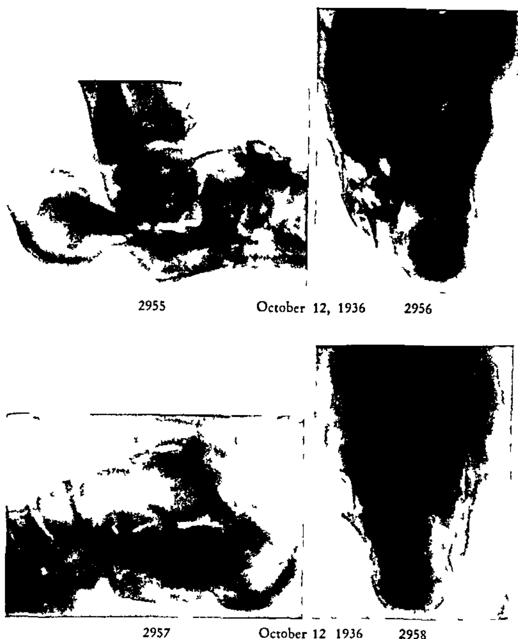
tuberosity The use of such supporting braces which protect against weight-bearing prevents exercise of the leg and the stress on the bone necessary for muscle development and increase of bone calcium content The decalcification usually persists until the patient is relieved of his brace

Treatment of Fresh Open Fractures of the Calcaneus

Mechanism Damage to the skin on the inner and outer aspect of the heel and breaking off of various processes of the calcaneus with exposure of the joints can result from being run over by a vehicle or by a crushing injury

Such fractures as occur in a fall from a great height or in an explosion with comminution of the bone and bursting of the skin on the sole as in figures 2829, 2951—2962 are much more severe

Treatment In all fresh open fractures the wound is carefully excised in accordance with the rules given in Vol I/pp 143—173 Then the skin and the skin alone is sutured without burying sutures or ligatures The open



2955 October 12, 1936 2956

2957 October 12 1936 2958

FIGS 2955—2958 —*Open* fracture of *both* calcanei sustained by a 16 year old patient in a leap from the second story On the right the tuber calcanei is completely sheared off and is displaced cranially by its full width Left there is parallel displacement cranially of the tuber calcanei by half its width Large burst wounds of both soles Painstaking wound excision and reduction in the screw traction apparatus Compression with the compression clamp

fracture is thus converted into a closed fracture and can be treated as such Figures 2951—2962 show that even the severest displacements can be reduced in the screw traction apparatus and that the reduction can be maintained by continuous traction If the skin is in satisfactory condition early arthrodesis should be carried out in 6 weeks

Covering of Skin Defects If skin loss with opening of tendon sheaths and joints has resulted from crushing, the defects must be covered with split grafts or pinch grafts after thorough wound excision (Vol I/pp 156—160)





2959 April 28 1938 2960





2961 April 28 1938 2962

Figs 2959—2962 —Same case after 1½ years Good form of both calcanei Tuber joint angle on the right restored Parallel displacement and broadening no longer present Rotation not possible Walks without symptoms Works as butcher Treated by Primarius Dr Glas in Eggenburg Lower Austria

Treatment of Infected Fractures of the Calcaneus

Before the introduction of antibiotics when infection followed open comminuted fractures, use of pins or wires or operative reduction of closed fractures it was often best to carry out amputation early because otherwise healing required many months or years and the final result was a poorly functioning foot Sometimes fatal sepsis developed The danger from infection has decreased In spite of antibiotics however healing is much delayed because of the development of fistulas and loss of skin

Treatment When relatively large cavities remain in the bone after removal of the sequestra it is best to make a longitudinal incision through the middle

of the insertion of the Achilles tendon and the sole, to expose the tuber calcanei subperiosteally and remove so much bone that the cavities disappear

When there is skin loss, especially dorsally so much of the bone should be removed in a similar manner until the normal skin can be closed without tension

Questions We Should Ask Ourselves in Order to Avoid Failures in the Treatment of Fractures of the Calcaneus Groups 4—8

1 Have I carried out a careful general examination and excluded patients with advanced generalized diseases (tabes, diabetes, arteriosclerosis, etc) and those over 60 years of age from active intervention?
2 Have I in these patients compressed the markedly broadened calcaneus between the heels of my thumbs under local or brief general anesthesia?
3 Have I in patients with severe concomitant injuries and in shock awaited an improvement of the general condition before reduction?
4 Have I focussed the central ray 1 cm below the tip of the medial malleolus in obtaining the lateral roentgenogram?
5 Have I in the plantar-dorsal roentgenogram focussed the central ray on the sole of the foot at an angle of 45°?
6 Have I obtained a plantar-dorsal and a lateral roentgenogram of the sound foot?
7 Have I fastened the Jeschke wire grid to the heel for the lateral roentgenogram?
8 Have I carefully measured the tuber-joint angle on both sides?
9 Have I checked the material listed on page 2082 for completeness and quality?
10 Have I mobilized the fragments of the tuber calcanei with the calcaneus compression clamp in fractures that were older than a week?
11 Have I located the correct point for introduction of the pin with the aid of the Jeschke wire grid?
12 Have I dorsiflexed the foot prior to driving in the pin?
13 Have I *inserted the pin in front of the posterior upper edge* and not through the middle of the tuber calcanei as in figures 2921 a, b?
14 Have I smoothed the points of entry and exit of the pin by finger pressure?
15 After fastening the rotating stirrup and the cap of the pin, have I turned the heads of the screws dorsally so that their shadow does not cover the fracture site in the roentgenogram?
16 Have I suspended the lower leg with a well padded sling so that I could exert backward and downward traction (fig 2942 a)?
17 Have I interposed a spring scale so that I could control the amount of traction exactly (fig 2942 a)?
18 Have I used traction of 5 to 6 Kg and never more than 10 Kg?
19 After traction downward and backward have I exerted horizontal traction of 5 to 6 Kg?
20 Have I overcorrected the tuber-joint angle by about 5°?

21 Have I obtained roentgenograms in both chief planes after reduction?
22 In fractures of group 5 have I lifted the superior joint surface with a Steinmann pin inserted into the fracture cleft from dorsal cranially if it remained depressed after the longitudinal traction?
23 In fractures of group 6 have I raised the depressed superior joint surface with a pin driven into the fragment from behind?
24 Have I avoided driving the pin for lifting the superior joint surface in groups 5 and 6 past the top of the fragment?
25 Have I after reduction corrected the broadening of the heel with both thumbs or with the calcaneus compression clamp?
26 Have I closed the compression clamp to 35 mm and *immediately opened it* in order to avoid damage to the skin by pressure?
27 Have I avoided applying a cast after reduction?
28 Have I left the points of entry and exit of the pin exposed and not covered by a dressing?
29 Have I placed the injured leg on a Braun splint under gentle traction after reduction
30 Have I applied no more than 3 kg for traction?
31 Have I suspended both pin ends so that the foot cannot turn?
32 Have I required the patient to move his toes actively through their full range from the first day on?
33 Have I obtained roentgenograms in both main planes after two days
34 Have I removed the pin immediately upon the appearance of the slightest redness of the point of entry or exit?
35 Have I after 8 to 10 days applied a long leg cast with extreme muscle relaxation, i e, with maximal plantar flexion in the ankle and right angle flexion in the knee after premedication with Pantopon or Trial?
36 Have I moved the leg in this position to the knee portion of the screw traction apparatus?
37 Have I had an assistant hold the leg continually in this position (fig 2942 c)?
38 Have I removed the pin?
39 Have I covered the points of entry and exit of the pin with the 2 × 2 cm sponges to which balsam of Peru had been applied?
40 Have I placed the 6 × 12 cm sterile sponge on the heel and Achilles tendon?
41 Have I placed the flannel strip around the upper end of the lower leg?
42 Have I applied a short leg walking cast?
43 Have I made a plantar dorsal and a lateral roentgenogram?
44 Have I suspended the leg with the knee at right angles and removed the knee portion of the screw traction apparatus?
45 Have I placed the flannel strip around the upper third of the thigh and crossed the two ends on the side and not in front?
46 Have I lengthened the cast to the upper third of the thigh?
47 Have I allowed the patient up with crutches after several days without bearing weight on the injured side?

48 Have I suspended the ankle from the opposite shoulder in order to maintain the lower leg in a horizontal position?
49 Have I obtained new roentgenograms after 4 weeks?
50 Have I removed the thigh and the knee part of the cast and placed the leg on a *Braun splint*?
51 Have I after two days placed the leg on an oblique splint with the knee extended?
52 Have I obtained new roentgenograms after 4 days?
53 Have I in the presence of satisfactory position applied a short leg walking cast for 4 weeks after correction of the plantar flexion?
54 Have I obtained new roentgenograms after removal of the cast?
55 Have I applied *an Unna paste dressing after removal of the short leg* walking cast?
56 If the position of the fragments was unsatisfactory or in the presence of comminution of the superior joint surface, have I carried out early arthrodesis of the talocalcaneal joint with a rotation bolt and using a three flanged nail?
57 Have I applied an Unna paste dressing two weeks later and allowed the patient to get up?
58 Have I applied a short leg walking cast for 2—3 weeks if pain on walking occurred?
59 Have I required the patient to exercise all joints of the foot and the entire body if this caused no pain?
60 Have I obtained roentgenograms at the completion of treatment?

Results of Treatment of Fractures of the Calcaneus

In the 10 years 1926—1935 I treated 250 fresh fractures of calcaneus Of these 247 were traumatic and three pathologic (two in tabes and one in poliomyelitis)

Since 19 (8 3%) had fractures of both calcanei we treated 228 patients who sustained 247 traumatic fractures of the calcaneus

Gollasch (see p 2074 footnote) has taken great pains to reexamine all patients within reach, clinically and roentgenologically In addition he reviewed all clinical records, insurance files and all roentgenograms He took a 10 months leave of absence in order to devote himself entirely to this problem 16 of the 228 patients had died at the time of reexamination in spring 1937, most of them from diseases of old age Of the 212 living 17 (7 9%) could not be reached 15 of these were not registered with the police (all Austrians are required to register change of address with the police within three days) and two had moved to another country Of the 212 patients still living, 195 more than 92%, were reexamined *About two thirds appeared after one or two requests* and one third were sent for by car and brought to the Accident Hospital because it was only here possible to carry out complete reexaminations and obtain the necessary roentgenograms I had the opportunity to see most of these patients together with Gollasch

In every single patient the following was noted at follow up examination

1 The patient's statement (a) Complaints especially in walking over uneven ground and in climbing stairs (b) Capacity for work and for walking (c) Whether patient resumed his previous work and date of such resumption

2 Clinical findings (a) Gait (b) Walking on tip toe (c) Mobility of the toes (d) Pronation and supination in the talonavicular and talocalcaneal joints (e) Plantarflexion and dorsiflexion in the ankle joint (f) Form of the foot (flat foot, etc) (g) Broadening of the heel (h) Callouses (i) Circulation (j) Tenderness of the heel to pressure (k) Muscle atrophy

3 Roentgenograms from the side and in plantar-dorsal direction From these the following were determined (a) The tuber joint angle in comparison with previous roentgenograms (b) The decalcification of the bones (c) Arthrosis deformans (d) Presence of arteriosclerosis (e) Changes in the length and breadth of the heel during the course of treatment (f) Correct or incorrect location of the pins in the calcaneus and in the tibia

The 247 fractures of the calcaneus in the 228 patients represented
0 36% of all fresh injuries,
2 09% of all fresh fractures and
10 10% of all fresh fractures of the foot

Age Distribution More than one fourth of the patients were in the fifth decade of life, 165 (71 5%) were 30 to 60 years of age Only 54 patients (23%) were less than 30 years old The age distribution of the various groups is variable since, in group 2, 50% are adolescents, while in groups 5—8 on the other hand only 14% are adolescents

Etiology Most fractures of the calcaneus resulted from falls The least height was 0 5 M and the greatest 16 M Most fell 2 to 4 M

Occupation Most patients belonged to the building trades

Associated Injuries Of the patients 34 (15%) suffered severe associated injuries namely fractures and dislocations Among these were six vertebra fractures Soft tissue injuries and brain concussion were not included Neither were the common shearing fractures of the posterior process of the talus of the same foot

Type of Treatment The 247 fractures of the calcaneus were treated in the following way

1	Walking cast	128
2	Tenotomy of the Achilles tendon	12
3	Transfixion	71
4	Continuous traction	39
5	Westhues	3
		247

Groups 1—3 and the milder cases of group 4 as well as such patients who were not subjected to any active intervention because of old age or because of generalized diseases belong to those patients treated by plaster immobilization alone All findings were listed by Gollasch for each patient

Duration of treatment was dependent on the severity of the injury and age Distribution of duration of treatment according to groups and according to age was as follows

Group	I	II	III	IV	V	VI	VII	VIII
Days	152	60	88	137	164	161	159	196

Age in years	10—30	31—40	41—50	51—60	61—70
Days	146	136	150	174	204

Deaths We lost a 37 year old man as a result of an infection which originated from a badly located pin Even though his temperature was over 38° C, reduction was carried out and he was given a cast with a pin through the calcaneus and one through the tibia The calcaneus pin was not located in the upper posterior area of the tuber calcanei but traversed the fracture cleft near the mid portion of the body of the calcaneus as shown in figures 2921 a, b Six days later the temperature rose to 39 5° C and pain appeared in the area of the tibia pin When it was exposed pus was seen at the location of the pin In spite of this the pin was not removed until 7 days later Then the pin through the calcaneus was also exposed and removed because the tissue surrounding it was also infected The temperature rose to 40° and large abscesses formed about the malleoli These were opened On the 29th day the leg was amputated In spite of this the patient died of sepsis on the 42nd day A metastatic abscess had developed in the left shoulder joint

In this case the pin which had been introduced into the incorrect place should have been immediately removed or at latest on the appearance of fever The patient was treated during my vacation

Local Infections Among the patients treated by continuous traction severe infection of the pin track occurred three times All three infections appeared in one week while all other cases healed without infection These also occurred during my vacation The pin was located incorrectly similar to that in figures 2921 a, b, and other mistakes were made

In addition five severe infections occurred in cases treated with the double *pin and cast In these the tibial pin was located incorrectly, namely too far* proximally or too far posteriorly so that the shaft of the tibia was split These cases also occurred during my vacation

For this reason I have abandoned treatment with the double pin and cast Its technique is too difficult for the inexperienced

Complaints All patients of group 2 had no complaints if there were no associated injuries Most of the patients of groups 3—8 had minimal or also moderate discomfort in walking on uneven ground The well reduced fractures never produced such severe symptoms as to hinder the patient in his work

Gait Only 11 (6%) of the 195 patients reexamined walked with a limp Three of these had severe associated injuries Only 3 patients used a cane when walking All three had severe vascular disturbances before their injury

Arch Supports 56% showed up for reexamination without arch supports They usually were no longer worn after 2 to 3 years

Ability to Walk on Tip toe Of the 195 reexamined patients, 28 (14%) were not able to walk on tip toe These were usually patients whose fractures could not be reduced for some reason or in whom a complication appeared during the treatment

Limitation of Motion in the Ankle Joint 32 patients (16%) had moderate limitation of motion in the ankle joint

Limitation of Motion in the Talocalcaneal Joint All patients of group 2 had complete mobility of all joints In groups 3—8, 15% had normal mobility of the talocalcaneal joint In 40% motion was limited and in 45% the joint was immobile

Limitation of motion of the toes occurred in 11 patients

Broadening of the heel was found in 32 patients (16%) and chiefly in those in whom reduction could not be carried out for some reason

Swelling and cyanosis was found in only four cases, namely in those with old vascular disturbances and in infections

Tenderness of the heel to pressure was always present in the first year in cases of groups 4—8 It later gradually disappeared

Traumatic flatfoot in those in whom the tuber-joint angle was 0° or less was present in 33 cases Of these 17 were immobilized for too short a period of time, in five the treatment had to be discontinued because of infection and in 11 the fracture was not reduced because of age blood vessel calcification or severe associated injuries

Foot contractures were found in nine cases Five of these had had an infection In three cases primary vascular disturbance was present and in one case reduction was not complete Only one of these nine patients used a stick for walking

Muscle atrophy was never found in groups 2 and 3, in groups 4—8 it was never more than 1 5 cm

Limitation of motion of the toes, inability to walk on tip toe, limitation of motion of the ankle joint and the foot contracture usually occurred together The seven vacation cases with pin track infections showed the severest disturbances In the others the disturbances were more the result of old age, overweight and vascular disturbances rather than the severity of the injury,

Since traumatic flatfoot and the foot contracture usually led to limitation of motion in the ankle joint and to inability to walk on tip toe one should endeavor to avoid these by all means

Resumption of Previous Work Four of the 195 reexamined patients were without occupation and three were out of work Of the other 188, 147 have resumed their previous trade among the building trades or as painters, 41 (26%) did not resume their previous work Among these were seven cases with damage as the result of treatment, chiefly infections The others were mostly old individuals with blood vessel calcifications which were recognizable in the first roentgenogram immediately after the injury

Disability Compensations Of the 228 patients 180 (70%) were covered by industrial accident insurance while 48 (21%) were not

The 180 insured were distributed as follows





2963 April 3, 1936 2964





2965 April 3 1936 2966

Figs 2963 2964 — Very severe fracture dislocation in Chopart s joint with inward and upward displacement of the foo and shortening Comminution of the cuboid and the lateral part of the navicular Fracture of the calcaneus group 2 with unusually severe displacement Simultaneous severe fracture of the first lumbar vertebra Sustained by the woman pi tured in Vol I/figs 507 to 511 in a fall from the second story

Figs 2965 2966 — Same case after reduction under local anesthesia The forefoot was pulled downward and laterally over a wedge (fig 2816) The position was maintained with two pins in a plaster cast that was *immediately* split The markedly displaced fragment of the calcaneus was later operatively removed Currently we fix the fragments with several Kirschner wires after reduction

a Unilateral fractures of the calcaneus	115
b Bilateral fractures of the calcaneus	11
c Severe infections	6
d Fractures of the calcaneus with severe associated injuries	26
e Fractures of the calcaneus of the year 1935	22
	180



2967 May 15 1935 2968



2969 September 28 1935 2970

Fig 2967 –Roentgenogram of the tarsus of a man who slipped on a stair and developed marked swelling and pain in the region of Chopart s joint No sign of a bone or joint injury

Fig 2968 –Comparison roentgenogram to fig 2967 after local anestesia in held adduction The foot is displaced inward The joint between calcaneus and cuboid is opened out and the navicular is displaced inward as signs that the ligaments are torn

Fig 2969 –Avulsion of bone from the navicular tuberosity and at the lateral wall of the cuboid after the foot was run over by the wheel of a car Chopart s joint was abnormally mobile

Fig 2970 –Avulsion of the navicular tuberosity incurred during forceful inward rotation of the lower leg on the fixed foot If after this fracture the foot is not immobilized for a sufficient period namely at least 6 weeks with the forefoot in adduction and pronation severe traumatic flatfoot will develop because the talus sinks lower and rotate inward

Fractures of the calcaneus with severe associated injuries and those from the year 1935 were not included, because in the former a disability pension was often given because of the associated injury and the latter could not be finally evaluated since the final state is not reached as a rule after two years

Of the 115 unilateral fractures of the calcaneus the average initial pension and the average duration of compensation is presented

Group	Average initial Pension	Duration of Compensation in Months
II	16 8%	12
III	19%	25 4
IV	26 5%	30
V	35%	42 7
VI	32%	60
VII	30%	51 7
VIII	39%	60

From this the relation of the severity of the fracture to the average initial amount of the disability pension and the duration of receipt of the pension can be seen

In all statistics regarding disability pensions it must be emphasized that the fact that the patient does not receive a disability pension does not mean that he has no symptoms There are a number of patients who still have pain but no longer draw disability compensation They are, however, not significantly hindered in their work by their symptoms

Noteworthy is the fact that we now have only few persons drawing permanent disability pensions, i e, patients with severe disability whereas permanent disability pensions are common among patients whose fractures of the calcaneus were not reduced *Here must be noted that in 1934 all* pensions under 20% were discontinued

Of the 115 unilateral fractures of the calcaneus 1 (0 9%) receive permanent disability pension

Of the 11 patients with bilateral fractures of the calcaneus 3 (27%) receive permanent disability pension

Of the 6 badly infected fractures of the calcaneus 4 (67%) receive permanent disability pension

One can see from these figures that infections give rise to the severest disturbances In the last 4 years, as the result of appropriate measures during vacation time no severe infection occurred

121 DISLOCATIONS IN CHOPART'S JOINT

Mechanism Complete or partial dislocation in Chopart's joint result from falls from great heights (figs 2951, 2963, 2964) from slipping (figs 2968 2970) or from being run over (fig 2969) The partial dislocations in fractures of the calcaneus group 7 usually are the result of a fall (fig 2901)

Anatomic Changes Complete dislocations (figs 2951 2963, 2964) are very rare They are never pure *dislocations but are always associated with extensive* avulsions of bone from the cuboid and the navicular or with comminution

of the calcaneus In the partial dislocations either the ligaments are partially torn (fig 2968) or the tuberosity of the navicular is torn off (fig 2970) In rare cases there are bony avulsions of the tuberosity of the navicular and of the lateral side of the cuboid (fig 2969)

Displacements The foot is either displaced inward and upward (figs 2951, 2963 2964, 2968) or outward (fig 2970) In fractures of the calcaneus group 7 the foot is displaced downward (fig 2901)

Possible Complications of Dislocations in Chopart's Joint If a complete dislocation is not reduced the foot remains deformed in a club foot position and is stiff and painful In the partial dislocations usually a traumatic flat foot results In addition decalcification is exceedingly prolonged

Avoidance of Complications They can be avoided if the dislocations are completely reduced and then immobilized The complete dislocations should be fixed with Kirschner wires and in the partial dislocations a lower leg walking cast is adequate Appropriate exercise should be carried out We formerly utilized a double pin or double wire plaster cast after reduction in complete dislocations

Treatment of Complete Dislocation in Chopart's Joint

The same materials are required for reduction and treatment as for malleolar fractures (see p 1917)

Clinical Examination The pulse, reflexes sensibility, ability to move the toes and the ankle joint should be tested on both sides as in every injury of the foot

Roentgenograms Anterior and lateral roentgenograms should be obtained of the talonavicular joint (figs 2963, 2964)

Anesthesia Reduction is possible in fresh injuries under local anesthesia Since two or three Kirschner wires are required for fixation it is better to use general or spinal anesthesia or sciatic block

Time of Reduction Reduction is usually easily achieved if the foot is bent downward and inward (figs 2965, 2966) over a wooden wedge (fig 2816) or over the edge of a table (fig 2816 a)

First Roentgen Check Roentgenograms are made in both main planes after reduction An assistant holds the foot in position while the roentgenograms are made

Placement of the Kirschner Wires Since in addition to the dislocation the navicular and the cuboid are comminuted it is only possible to maintain the reduction achieved by transfixion with Kirschner wires While an assistant holds the foot in reduced position, two wires are drilled through the first cuneiform and the navicular into the talus and are cut off below the skin (fig 2977 b)

Application of a temporary short leg cast roentgen check, splitting the cast, supporting of the leg in bed and exercise are carried out as for malleolar fractures (see pp 1920—1927)

Application of the short leg walking cast is carried out as described on page 1928

Fractures of the calcaneus with severe associated injuries and those from the year 1935 were not included, because in the former a disability pension was often given because of the associated injury and the latter could not be finally evaluated since the final state is not reached as a rule after two years

Of the 115 unilateral fractures of the calcaneus the average initial pension and the average duration of compensation is presented

Group	Average initial Pension	Duration of Compensation in Months
II	16 8%	12
III	19%	25 4
IV	26 5%	30
V	35%	42 7
VI	32%	60
VII	30%	51 7
VIII	39%	60

From this the relation of the severity of the fracture to the average initial amount of the disability pension and the duration of receipt of the pension can be seen

In all statistics regarding disability pensions it must be emphasized that the fact that the patient does not receive a disability pension does not mean that he has no symptoms There are a number of patients who still have pain but no longer draw disability compensation They are, however, not significantly hindered in their work by their symptoms

Noteworthy is the fact that we now have only few persons drawing permanent disability pensions, i e, patients with severe disability, whereas permanent disability pensions are common among patients whose fractures of the calcaneus were not reduced Here must be noted that in 1934 all pensions under 20% were discontinued

Of the 115 unilateral fractures of the calcaneus 1 (0 9%) receive permanent disability pension

Of the 11 patients with bilateral fractures of the calcaneus 3 (27%) receive permanent disability pension

Of the 6 badly infected fractures of the calcaneus 4 (67%) receive permanent disability pension

One can see from these figures that infections give rise to the severest disturbances In the last 4 years, as the result of appropriate measures during vacation time, no severe infection occurred

121 DISLOCATIONS IN CHOPART'S JOINT

Mechanism Complete or partial dislocation in Chopart s joint result from falls from great heights (figs 2951, 2963, 2964), from slipping (figs 2968, 2970) or from being run over (fig 2969) The partial dislocations in fractures of the calcaneus group 7 usually are the result of a fall (fig 2901)

Anatomic Changes Complete dislocations (figs 2951, 2963, 2964) are very rare They are never pure dislocations but are always associated with extensive avulsions of bone from the cuboid and the navicular or with comminution

of the calcaneus. In the partial dislocations either the ligaments are partially torn (fig. 2968) or the tuberosity of the navicular is torn off (fig. 2970). In rare cases there are bony avulsions of the tuberosity of the navicular and of the lateral side of the cuboid (fig. 2969).

Displacements. The foot is either displaced inward and upward (figs. 2951, 2963, 2964, 2968) or outward (fig. 2970). In fractures of the calcaneus group 7 the foot is displaced downward (fig. 2901).

Possible Complications of Dislocations in Chopart's Joint. If a complete dislocation is not reduced the foot remains deformed in a club foot position and is stiff and painful. In the partial dislocations usually a traumatic flat foot results. In addition decalcification is exceedingly prolonged.

Avoidance of Complications. They can be avoided if the dislocations are completely reduced and then immobilized. The complete dislocations should be fixed with Kirschner wires and in the partial dislocations a lower leg walking cast is adequate. Appropriate exercise should be carried out. We formerly utilized a double pin or double wire plaster cast after reduction in complete dislocations.

Treatment of Complete Dislocation in Chopart's Joint

The same materials are required for reduction and treatment as for malleolar fractures (see p. 1917).

Clinical Examination. The pulse, reflexes, sensibility, ability to move the toes and the ankle joint should be tested on both sides as in every injury of the foot.

Roentgenograms. Anterior and lateral roentgenograms should be obtained of the talonavicular joint (figs. 2963, 2964).

Anesthesia. Reduction is possible in fresh injuries under local anesthesia. Since two or three Kirschner wires are required for fixation it is better to use general or spinal anesthesia or sciatic block.

Time of Reduction. Reduction is usually easily achieved if the foot is bent downward and inward (figs. 2965, 2966) over a wooden wedge (fig. 2816) or over the edge of a table (fig. 2816 a).

First Roentgen Check. Roentgenograms are made in both main planes after reduction. An assistant holds the foot in position while the roentgenograms are made.

Placement of the Kirschner Wires. Since in addition to the dislocation the navicular and the cuboid are comminuted, it is only possible to maintain the reduction achieved by transfixion with Kirschner wires. While an assistant holds the foot in reduced position two wires are drilled through the first cuneiform and the navicular into the talus and are cut off below the skin (fig. 2977 b).

Application of a temporary short leg cast, roentgen check, splitting the cast, supporting of the leg in bed and exercise are carried out as for malleolar fractures (see pp. 1920—1927).

Application of the short leg walking cast is carried out as described on page 1928.

Duration of Immobilization The cast and the wires are removed after 10 weeks

Further Treatment After removal of the cast an Unna s paste dressing is applied and arch supports used (see pp 1930, 1931)

Treatment of Partial Dislocations in Chopart s Joint

Clinical Examination After the pulse, reflexes, sensibility, active mobility of the toes and ankles have been tested on both sides, one examines for abnormal mobility The foot is markedly swollen in the region of the talonavicular joint Since the joint is usually immobile because of painful spasm it is first anesthetized with local anesthesia



2970 a November 19 1933

Open dislocation of the navicular laterally and dorsally The bone is so rotated that the joint surface for the talus faces obliquely plantarwards and heelwards Sustained by a 36 year old railroad worker who while jumping off a train fell and was dragged 250 M *Treatment* Because of simultaneous severe soft tissue injury immediate amputation was performed at the lower leg These roentgenograms are taken from a publication by Leitner [1]

Roentgenograms If after local anesthesia roentgenograms are made with the joint in stress abnormal mobility can be well demonstrated (figs 2967, 2968) This is proof that the ligaments are torn in the region of Chopart s joint

Reduction is usually easy

Application of the temporary short bed cast and the walking cast follows as in malleolar fractures (see pp 1920—1928)

Period of Immobilization The walking cast can be removed after 6 weeks

Exercise and further treatment are carried out as for malleolar fractures (see pp 1930, 1931)

Vigorous massage and forced passive movements adversely affect healing especially if they are instituted immediately after the injury, because prolonged swelling and marked decalcification develop as a result The foot then remains painful for months and can bear weight only cautiously, while with adequate

[1] Leitner Baldo Luxatio ossis navicuları pedis Arch orthop Unfallchir *46* 55—57

immobilization in plaster it is usually useful within two weeks after immobilization has been discontinued

Rotation Bolt Arthrodesis of Chopart's Joint In the presence of severe comminution of the joint it is best to carry out early arthrodesis in order to avoid later painful arthroses If these have already appeared a late arthrodesis can now be carried out The talonavicular joint is exposed medially and the calcaneo cuboid joint laterally with appropriate longitudinal incisions

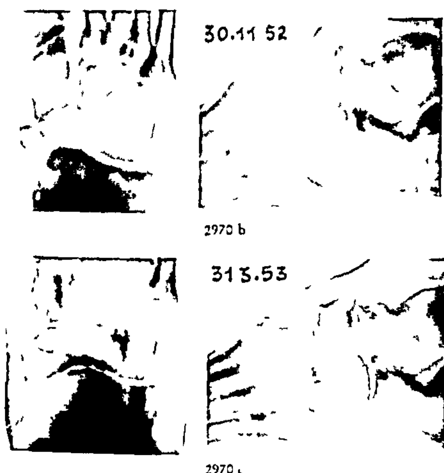
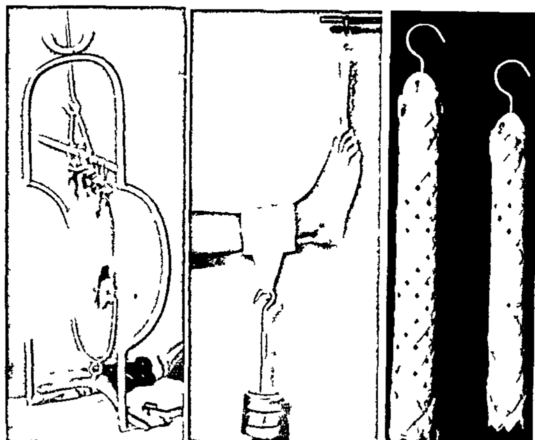


Fig 2970 b – Fracture dislocation of the right navicular Sustained by a 48 year old farm worker in a fall with a motorcycle The navicular is fractured in its lateral plantar portion and pressed together The medial dorsal portion has been forced out of the joint and projects 15 mm dorsally and 10 mm medially *Treatment* Reduction over a plantar placed wedge (fig 2816) Thereupon roentgenograms showed very good position in both main planes Temporary split cast in plantar flexion for 2 weeks then walking cast for an additional 8 weeks

Fig 2970 c – Same case after 4 months Navicular healed in good position The medial and dorsal dislocation is no longer present Bone atrophy 5 5 months after injury walks without a limp Toes freely mobile Talocalcaneal joint motion limited by ½ Ankle joint 80° to 105° as compared to 80° to 125° on the left

and a rotation bolt arthrodesis in carried out with the Scherbichler instrument (figs 2765—2769) After the operation a temporary lower leg cast is applied for 2 weeks (see pp 1917—1927) followed by a lower leg walking cast for an additional 10 weeks Further treatment is carried out as for malleolar fractures (see pp 1930, 1931)



2971 November 2 1928 — 2972 January 4 1957 — 2972 a May 3 1951

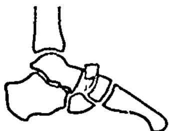
Fig 2971 —Screw traction apparatus for the upper arm utilized for reduction of a fracture dislocation of the navicular of the foot Traction is exerted on a calcaneus pin and counter traction on the pads of the toes with stainless wire A wire can be drilled through the base of the metatarsals instead It is better to direct the chest portion of the screw traction apparatus toward the body in order to achieve plantar flexion during traction Currently we usually carry out reduction of fracture dislocations of the navicular by vigorous plantarflexion over a padded wooden wedge (fig 2816) or over the padded edge of a table (fig 2816 a)

Fig 2972 —Reduction of a fracture dislocation of the navicular or the first metatarsal The great toe is supplied with a finger trap and is suspended from a horizontal bar or from a hook in the ceiling For countertraction appropriate weights are suspended from the leg above the ankle by means of a padded web belt or a sling In dislocations or fractures of several metatarsals every toe is supplied with a finger trap or a traction bandage

Fig 2972 a —So called finger traps compressible of woven straw for suspension of toes and fingers

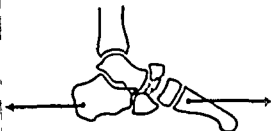
122 DISLOCATIONS OF THE NAVICULAR, THE CUBOID AND THE CUNEIFORMS

Dislocations of the navicular the cuboid and the cuneiforms are rare Complete dislocations of the navicular are always open Of the cuneiforms usually only the first is dislocated If reduction cannot be achieved over the wooden wedge (fig 2816) or the edge of the table (fig 2816 a) the foot is placed in the screw traction apparatus as for fracture-dislocations of the navicular (figs 2971—2977) or the same traction arrangement as is used for





2976 November 2 1928





2973—2975 December 12 1928

2977 November 2 1928

Fig 2973 —Fracture dislocation of the navicular The talus and the cuneiforms have approach d each other and the navicular is comminuted in its lower portion and pressed out of the joint in its upper portion

Fig 2974 —The space between the talus and the cuneiforms is widened by traction on the calcaneus and the first metatarsal Currently we carry out reduction by forceful plantarflexion over a padded table edge as in fig 2816 a The space between the head of the talus and the cuneiforms is widened even more The tensed ligaments and extensor tendons press the dislocated navicular fragment back into the joint

Fig 2975 —Reduction is now easily achieved by pressure on the disloca ed navicular

Fig 2976 —Fracture dislocation of the navicular

Fig 2977 —Same case By means of screw traction (fig 2971) the space between the talus and the cuneiforms was widened and then by pressure of the aluminum pads of the calcaneus compr ssion clamp the dislocated navicular was pressed back The comminuted bone has again been completely unfolded The reduction is more simply and much more easily achieved by plantarflexion

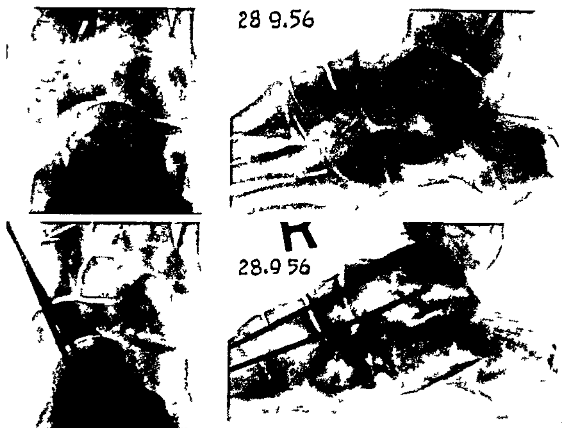
fractures of the metatarsal (fig 2998) At the present time we use a well padded sling with a weight in place of the pin through the calcaneus and Chinese finger traps (fig 2932) in place of the wires through the pads of the toes After reduction a temporary lower leg bed cast is applied (see pp 1917—1927) for a week followed by a lower leg walking cast (see p 1928) for 5 weeks

Exercise and further treatment are carried out as for malleolar fractures (see pp 1928—1931)

123 FRACTURE DISLOCATIONS OF THE NAVICULAR

Mechanism Fracture-dislocations of the navicular are usually sustained by jumping and landing on the plantarflexed foot

Anatomic Changes and Displacements As the result of the sudden forceful plantarflexion the ligaments on the dorsum of the foot tear and the navicular



2977 a b

Fig 2977 a —Dorsal and tibial subluxation of the foot in Chopart s joint with fracture of the calcaneus cuboid and navicular as well as avulsion of the tip of the fifth metatarsal Sustained by a 41 year old engineer who weighed 83 kg and was 172 cm tall when a 7 M long ladder slipped with him

Fig 2977 b —Same case after reduction over a padded table edge and with the Phelps Godit osteoclast after the insertion of two parallel wires from the navicular into the talus The wires have not yet been cut off The dorsal and tibial subluxation in Chopart s joint have been corrected The compressed navicular has again been unfolded The joint between navicular and cuneiforms is again well delineated An arthrodesis of the talocalcaneal joint and Chopart s joint was later carried out

pops out of the joint with its dorsal and medial portion In the next moment the heel strikes the ground and marked dorsiflexion is produced As a result the plantar and lateral portion of the navicular which is not displaced is crushed between the head of the talus and the cuneiforms (figs 2973, 2976 2977 a)

Possible Complications of Fracture-dislocations of the Navicular Without adequate reduction and immobilization healing in mild club-foot position results and painful arthroses develop in front of and behind the navicular

Avoidance of Complications after Fracture-Dislocations of the Navicular These complications can often be avoided by exact reduction and adequate immobilization In the presence of severe comminution of the navicular it is often best to carry out an early arthrodesis

Treatment of Fracture Dislocations of the Navicular

The following materials are required for reduction and treatment

1 Good AP and lateral roentgenograms
2 Local, general or spinal anesthesia (see Vol I/p 125, fig 152)
3 A 6 cm wide 50 cm long strap or a strong bandage (fig 2972)
4 A quilted cotton pad 0 5 × 10 × 18 cm (fig 2972)
5 Four to five Chinese finger traps of proper size (fig 2972)
6 Two sets of weights of 5 Kg each (fig 2972)
7 Five stainless steel wires which have been filed to a point on one end 0 5 mm thickness and 30 cm long (fig 2971)
8 A sterile needle holder
9 Five small pieces of wood to be used as spreaders (Vol I/fig 148, fig 2971)
10 A round wooden dowel 15 cm long and 1 cm in diameter (fig 2971)
11 A screw traction apparatus for the upper arm (Vol I/fig 106, fig 2971) or for the forearm (Vol I/fig 107)
12 Three to four stainless steel Kirschner wires 2 mm in diameter and 100 cm long
13 An electric or pneumatic bone drill (Vol II/figs 1696—1698)

Clinical Examination As in every injury of the foot, the active mobility of the toes and ankle joint sensibility and pulses should be examined The dislocated navicular can be seen and felt in the first hours Later marked swelling develops

Roentgenograms Then good roentgenograms should be obtained from the side (figs 2970 b 2976, 2977 b) and dorso-plantar (fig 2977 a)

Time of Reduction Since the comminuted portion of the navicular can no longer be unfolded after several days, it is best to carry out reduction on the first day

Anesthesia Usually local anesthesia is adequate General or spinal anesthesia is rarely required

Reduction Over a Table Edge Usually reduction can be achieved by plantar flexion and simultaneous abduction of the forefoot over a table edge which has been padded by a folded towel (fig 2816 a) The narrowed space between the head of the talus and the first cuneiform (figs 2970 b 2974 2976) is thus widened and the dislocated navicular can be pressed into the joint by pressure of the thumb or the heels of the thumbs (figs 2970 c, 2975 2977)

Roentgen Check After reduction roentgenograms are made from both sides

Immobilization After reduction the foot should be held continuously in good position with both hands When the roentgenograms show good

position a temporary short leg cast is applied in the manner described on pages 1917—1927

Roentgen Check After the application of the cast new roentgenograms are obtained from both sides

Application of the Short Leg Walking Cast and Roentgen Check When the swelling has receded after 8 to 10 days a short leg walking cast is applied



2977 c October 11 1938 2977 d

Fig 2977 c —Dorsoplantar exposure of the tarsus by vertical direction of the central ray Lisfranc s joint and the joints of the cuboid are not well seen

Fig 2977 d —Lateral view of the tarsus

in the manner described on page 1928 Then new roentgenograms should be obtained and repeated every 2 to 3 weeks

Duration of Immobilization The cast is removed 10 weeks after the injury

Further treatment in an Unna s paste dressing arch supports and exercise is carried out as for malleolar fractures (see pp 1930, 1931)

Reduction with Web Strap and Finger Traps or Traction Bandages If reduction cannot be achieved by plantarflexion and abduction over the padded table edge one should attempt to correct the shortening by prolonged traction The great toe is provided with a finger trap or a traction bandage and suspended *A weight of 5 to 10 Kg is suspended from the leg above the ankle* (fig 2972) When the joint space is enlarged after a few minutes the dislocated navicular is pressed into place

Roentgen check, immobilization and further treatment follow as after reduction over the padded table edge (see pp 2121, 2122)

Reduction in the Screw Traction Apparatus with Wires Through the Toe Pads If the finger trap does not hold the toe satisfactorily one can use a sterile pointed wire placed through the pad of the toe with a needle holder instead of the traction bandages We no longer use traction with a pin through the calcaneus as illustrated in figures 2971 and 2977

Roentgen check, immobilization and further treatment are carried out as after reduction over the padded table edge (see pp 2121, 2122)



2977 e November 11 1938 2977 f

Fig 2977 e — Dorsoplantar exposure of the tarsus with oblique direction of the central ray from in front above to behind below at an angle of 30° The joints at the base of the metatarsals are visible

Fig 2977 f — Dorsoplantar exposure of the tarsus with oblique direction of the central ray from lateral above to medial below at an angle of 30° The joints about the cuboid navicular and cuneiform are completely shown

Fixation with Kirschner Wires In unstable fractures of the navicular two wires can be drilled from the first cuneiform through the navicular into the head of the talus (fig 2977 b) and the cast can be applied

The transfixion cast with a pin or a wire through the calcaneus and a second through the base of the metatarsals is no longer used by us because the distraction in the screw traction apparatus often leads to severe decalcification and limitation of motion

Early Arthrodesis After Fracture-dislocations of the Navicular by the Rotation Bolt Procedure If the navicular is not completely replaced and unfolded or if the displacement recurs it is best to perform an arthrodesis

position a temporary short leg cast is applied in the manner described on pages 1917—1927

Roentgen Check After the application of the cast new roentgenograms are obtained from both sides

Application of the Short Leg Walking Cast and Roentgen Check When the swelling has receded after 8 to 10 days a short leg walking cast is applied



2977 c October 11 1938 2977 d

Fig 2977 c —Dorsoplantar exposure of the tarsus by vertical direction of the central ray Lisfranc s joint and the joints of the cuboid are not well seen

Fig 2977 d —Lateral view of the tarsus

in the manner described on page 1928 Then new roentgenograms should be obtained and repeated every 2 to 3 weeks

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Roentgen check, immobilization and further treatment follow as after reduction over the padded table edge (see pp 2121, 2122)

if the central ray is angulated 30° from dorsal in front to plantar behind with the foot flat (fig 2977 e) Lisfranc's joint can also be shown if the patient is placed face down and the exposure is made with the central ray directed vertically to the dorsum of the foot

In order to obtain a good view of the joint surfaces of the cuboid, the exposure must be obtained obliquely from the lateral side (fig 2977 f) Exposures of the foot must be made with the central ray directed in various angles in order to obtain a good view of the different bones in the lateral roentgenogram also The usefulness of these oblique exposures is illustrated especially well in figures 2978—2980

Treatment Since these fractures seldom show much displacement, reduction is not necessary The swelling is pressed away after local anesthesia Then a temporary short leg cast is applied (see pp 1917—1927) followed by a short leg walking cast for an additional 8 to 10 weeks (see p 1928)

If skin necroses appear the short leg walking cast should not be applied until these have healed

Exercise and further treatment are carried out as for malleolar fractures (see pp 1930, 1931)

Massage and passive motion are devastating in these fractures if they are begun soon after the injury If weight bearing is begun without an immobilizing cast the foot will always be painful and swell markedly A centripetal joint irritation reflex results from the pain The circulation is then impaired and swelling follows passive hyperemia leading finally to marked decalcification of the bones As a result they lose their ability to bear weight and weight bearing becomes more and more painful When the irritation of passive motion is added to that of weight bearing the disturbances become especially severe and prolonged

125 GUNSHOT WOUNDS OF THE TALAR JOINTS

Incidence These are the third most common gunshot injuries of joints in the series of Jimeno-Vidal[1] and in my series Vidal's 1296 gunshot wounds of joints are distributed as follows knee 433 (32 7%), elbow 290 (22 3%), talar joints 238 (18 3%), wrist 199 (15 2%) shoulder 81 (6 2%) and hip 55 (4 3%) My cases are listed in Vol I/pp 198—206

Distribution Of the 238 gunshot wounds of talar joints 98 (41 1%) involved the supratalar compartment (talocrural joint), 87 (36 6%) the subtalar compartment (talocalcaneal and talonavicular joints), and 53 (22 3%) involved both the supra- and the subtalar compartments

Of the 98 gunshot wounds of the supratalar compartment 68 (28 6%) involved the bones of the lower leg, the medial and the lateral malleolus each 23 times and otherwise the lower end of the tibia, 24 (10%) involved the bones of the lower leg and the talus and 6 (2 5%) involved the capsule only

Of the 87 gunshot wounds of the subtalar compartments the anterior was involved 33 times (13 9%), the posterior 36 times (15 1%), and both were

[1] Jimeno Vidal Sprunggelenkschusse Erfahrungen aus dem Spanischen Burgerkrieg 1936 bis 1939 *41* 711—729 1942

4 to 6 weeks after the injury in order to avoid painful arthroses The joint between the head of the talus and the navicular as well as that first cuneiform and the navicular is exposed by a longitudinal incision and a bolt is cut out and rotated for each of the joints with the Scherbichler instrument (figs 2765—2769) Or the three bones can be united with a slotted bone graft After the operation a temporary short leg cast is applied for 2 weeks followed by a short leg walking cast for an additional 10 weeks (see p 1928) Further treatment is carried out as for malleolar fractures (see pp 1930, 1931)

Avulsion Fractures of the Tuberosity of the Navicular Mechanism These result from marked abduction of the forefoot The tuberosity of the navicular is avulsed by the pull of the tibialis posterior muscle The displacement is usually slight If roentgenograms are made with abduction stress under local anesthesia lateral subluxation can usually be seen in Chopart s joint Sometimes the os tibiale externum is mistaken for an avulsion fracture It can be differentiated by the fact that its surface opposite the navicular is smooth and shows no sharp irregularities as seen in a fresh fracture This differentiation is important so that superfluous prolonged plaster immobilization *is not carried out for this anomaly*

Treatment In order to avoid a traumatic flat foot the foot should be immobilized in a temporary cast until the swelling recedes and then in a short leg walking cast for an additional 10 weeks as for a malleolar fracture (see pp 1917—1927) Further treatment is also carried out in the same manner (see pp 1930, 1931)

124 FRACTURES OF THE CUBOID AND OF THE CUNEIFORMS

Mechanism Fractures of these short bones usually are the result of a direct injury like being struck by heavy falling objects or in being run over An indirect mechanism as in a *jump* or a sharp inward or outward rotation is much less common

Clinical Diagnosis There is often severe swelling Sometimes blebs and skin necroses occur The magnitude of the swelling is in proportion to the magnitude of the force producing the injury The fractured bones are tender to pressure, traction and impaction

Roentgenologic Diagnosis With standard roentgen technique usually only small chip fractures are seen For this reason in the presence of marked swelling stress roentgenograms should be obtained under local anesthesia Subluxation of the neighboring joints are often seen on these pictures

Technique for the Roentgenogram of the Root of the Foot Since the root of the foot is arched longitudinally and transversely and the lateral surfaces of these bones are not parallel as they represent structural segments of the arch, they are not entirely satisfactorily shown in the standard roentgenogram obtained exactly from the front and exactly from the side, because they are partially superimposed *on one another* Since, for example the anterior surfaces of the cuneiforms and the cuboid (Lisfranc s joint) extend obliquely from dorsal in front to plantar behind Lisfranc s joint can only be shown

Suture of the joint capsule is always recommended in theory but can usually not be carried out in practice

The attempt to sterilize the joint with the old chemical agents has never in my experience produced the desired result and should therefore be omitted, because the joint is thus irritated One should however always prescribe antibiotics

Amputation should be carried out at once when there is extensive disruption of soft tissue or when several bones are thoroughly comminuted The comminution of the bones only without extensive soft tissue damage may not be considered as an indication for amputation The amputation stump may not be sutured

Avoidance of inflammation of the wound and alleviation of pain The best means of avoiding inflammation of the wound and of prolonged relief of pain is the complete uninterrupted immobilization of the foot in the temporary short leg cast after thorough excision of the wound If the tibia has been injured the cast should extend to mid thigh

He who has sufficient experience in thorough wound excision (Vol I/pp 149—174) and who can observe the patient for at least 3 days may suture the skin after the insertion of a rubber drain If the course is uncomplicated the drain should be removed after 24 to 48 hours In addition antibiotics should be given

Splinting for Transport to the Special Army Hospital for Gunshot Fractures and for Gunshot Injuries of the Joints Gunshot wounds of the ankle should as soon as possible after wound excision be sent to a hospital specializing in fractures and gunshot injuries of joints where they can remain continuously until complete healing The best splint for transportation is the padded *windowed plaster cast* that extends from the tips of the toes to the knee It is applied as for malleolar fractures (see pp 1917—1927) Non-padded casts can only be used if the wound has been thoroughly excised Otherwise they must be padded *Unpadded casts must always be split*

All patients with fresh casts must be kept warm after their application and during transportation

Splints If there are no facilities for applying a plaster cast the leg is placed in a gutter splint or in a double Cramer splint

Windowing and inscription of the cast is carried out as for gunshot fractures of the femur (Vol II/p 1148)

FINAL TREATMENT IN THE SPECIALIZED HOSPITAL

Roentgenograms If there is no urgent reason to remove the transportation cast, roentgenograms are made in both main planes

Treatment of Aseptic Gunshot Wounds of the Talar Joints

If no noteworthy displacement is present and the transportation cast fits well it can be left until the swelling has receded

Treatment of aseptic gunshot wounds of the talar joints with displacement in the ankle joint (upper compartment) After removal of the transportation

involved 18 times (7 6%) Of *the* 33 *cases with injury of the anterior compartment* the calcaneus was injured 22 times, the talus 23 times, the navicular 15 times, the cuboid 11 times and the cuneiforms 6 times

In the open injuries to the posterior compartment the calcaneus is often markedly comminuted The tuber-joint angle (figs 2876—2884) is often reduced or even negative

Of the 53 patients with simultaneous injuries of the supra- and subtalar compartments the supra and the posterior subtalar compartments were involved more often than the supra- and anterior subtalar compartments Sometimes all three compartments were involved

Of the 238 gunshot injuries of the talar joints the talus was involved 118 times, the calcaneus 104 times, the lateral malleolus 45 times, the medial 29 times, the lower end of the tibia 23 times, the navicular 20 times and the cuneiforms 9 times

Type of Wounds Of the 238 patients 57 (23 9%) had puncture type through and through injuries, 62 (26 1%) moderately large wounds, 35 (14 6%) irregular wounds, 29 (12 2%) extensive wounds and 55 (23 2%) lodging wounds Sometimes large burst wounds are present on the heel in which are found unattached bone splinters

TREATMENT OF GUNSHOT WOUNDS OF THE TALAR JOINTS

Treatment at the First Aid Station or Clearing Station Treatment of shock, relief of pain, warming, prophylaxis against tetanus and administration of penicillin are carried out in the same manner as for gunshot wounds of the hip (see Vol II/pp 1143, 1144)

Every patient must receive tetanus antitoxin if he has not been actively immunized In addition he should be given depot penicillin or another antibiotic if it is available

Control of bleeding is usually achieved by elevation of the leg and application of a pressure bandage

Splinting for Transport to the Field or Station Hospital The leg is splinted in a gutter splint or on a well padded double Cramer splint

Treatment at the Field or Station Hospital

Application of heat treatment of shock and wound excision are carried out in the same manner as for gunshot fractures of the thigh (Vol II/p 148ɔ) Foreign bodies, especially fragments of leather from the shoes, which have often been driven into the cancellous bone, must be thoroughly removed as otherwise very severe wound infections will result In order to work rapidly and with precision the operation should be carried out in a field which is maintained bloodless by a tourniquet

In contradistinction to fractures of long bones *loose bone splinters should be removed* However one should never remove entire bones such as the talus the calcaneus or the navicular

Primary joint resection should not be carried out as it sometimes leads to flail joints and thus disrupts function

Achilles tendon and the tibia or less often downward toward the deep muscles of the sole These abscesses must be widely drained through lateral and medial incisions They must be carefully digitally explored in order to find the most remote pockets *Short rubber tubes or soft rubber drains are inserted These should not be inserted transversely through the foot or leg* as arrosion hemorrhage might result

In the presence of *gas phlegmon or malignant epifascial edema* multiple parallel incisions are made which extend a few cm into the normal tissue above and below It is thus usually possible to halt these malignant inflammations In all infections antibiotics should be administered

True gas gangrene does not occur with gunshot fractures of the ankle as there are no muscles in this area

Immobilization After wide incision of the abscesses in and around the joint progression of the inflammation can be hindered only by complete uninterrupted immobilization To achieve this a short leg cast is applied from the tips of the toes to the knee or in the presence of comminution of the distal end of the tibia to mid thigh The foot should be 5° to 10° plantarflexed and in mid position between pronation and supination, so that the heads of the five metatarsal are in the same plane The flexor aspect of the toes should be included in the cast to avoid flexion contracture of the toes The extensor aspect must remain exposed in order that one can observe the circulation and that the toes can be moved The longitudinal and transverse arches should be well molded Appropriate windows should be cut out over the wounds In addition antibiotics should be given

Further Treatment of Gunshot Wounds of the Talar Joints

Care of the wound is carried out in the same manner as for gunshot fractures of the femur (see Vol II/p 1492)

Exposed Wound Treatment As a rule it is best to leave the wounds exposed in a windowed cast If no abscesses are present, significant window edema as occurs over the tibia rarely develops

Prevention of Window Edema If the soft tissue swells in the exposed wound treatment in a windowed cast, healing of the wound ceases A light pressure dressing should then be applied If this is omitted the margins of the cast cut into the skin and pressure ulcers develop The edge of the cast is covered with zinc paste The wounds are left dry or covered with vaseline gauze The materials used for the pressure dressing must be carefully prepared so that they exactly fill the window in the cast and that there is no space along the edge of the cast In order to avoid bad odor where the bandage is to be left for a prolonged time boric acid powder is sprinkled on the various layers It is often well to leave the cast unwindowed

Incision of Fresh Abscesse If the fever does not abate or increases in spite of wide opening of the abscess and complete uninterrupted immobilization as well as the administration of antibiotics, one should determine by careful palpation whether new abscess pockets have developed In the presence of pus retention the granulations protrude and become glassy If much pus is expressed by pressure at any point a new incision should be made there,

cast a pin or a wire is driven through the calcaneus and continuous traction is applied as for closed tibiofibular shaft fractures (figs 2374, 2378)

Treatment of Infected Gunshot Wounds of the Talar Joints

Of the 238 gunshot injuries of the talar joints reported by Vidal, 182 (76 5%) were infected If only one chamber was opened the infection seldom extends to another as they are usually completely separated from one another

The inflammation is not as dangerous as in gunshot wounds of the hips or knee joint Therefore the mortality and the number of amputations is relatively small Ankyloses or marked restriction of motion is often found among the survivors or the unamputated Not uncommonly deformities of the foot similar to club foot, pes cavus or flatfoot result while pes equinus is common In addition flail joints and flexion contracture of the toes are relatively common Those of the great toe markedly impede walking Flexion contractures of the knees have also been observed

Most important in the treatment of every infected gunshot wound of a talar joint is *provision for escape of the pus and at the same time uninterrupted immobilization* in a cast, which extends from the tips of the toes to mid thigh At the same time antibiotics are administered Exercise of those joints not included in the cast and of the entire body may not be omitted A stable leg is much more important than a mobile leg that is painful Therefore everything should be done to avoid malposition and flail joints

Treatment of the inflammation by immobilization only Before the intro duction of the antibiotics mild infections often subsided following uninterrupted immobilization and elevation of the part In spite of antibiotics uninterrupted immobilization should always be carried out

Drainage of Pus *by an incision into the joint* When fever and swelling do not subside from immobilization alone, the joint must be opened under tourniquet ischemia The approach to the supratalar and the posterior sub talar chambers is by means of a curved incision which is begun behind the lateral malleolus between the Achilles tendon and the peroneus tendon The fat between the Achilles tendon and the ankle joint is divided exposing the capsule of the upper and the lower chambers The capsule is opened transversely Sometimes incisions must be made in front of the malleoli The ante rior lower chamber can only be reached from here

Drainage of the Pus by Removing the Talus or by Resection of the Joint Both are often recommended but are not necessary because the inflammation disappears in the course of a few weeks using uninterrupted immobilization after wide opening of the joint If the talus is removed or the joint is resected and in addition the malleoli are sawed off transversely, a flail joint not infrequently develops As a result the foot is not able to bear weight If the talus is left in place however bony ankylosis and good usability results if deformities are avoided by means of a suitable cast If in severe comminution of the lower end of the tibia all fragments are removed markedly shortening and a useless leg result

Drainage of Pus in Abscesses of the Capsule Phlegmons If the pus breaks through the capsule, it can spread proximally toward the calf between the

Duration of Immobilization *In aseptic gunshot wounds of the talar joints* immobilization of 8 weeks is adequate in the presence of minimal bone injury In the presence of infections bony ankylosis usually develops after 3 to 4 months If the cast is removed too early gross swelling develops and often inflammation occurs

Sequestrectomy After gunshot wounds of the talar joints sequestra often develop in the spongy bone of the talus and the calcaneus These appear in the roentgenogram as dense shadows in the surrounding decalcified bone Sequestra in the calcaneus are removed in the manner described on page 2105

Covering of Skin Defects Skin defects are covered with pinch grafts as in Vol I/figs 157—158 a and figs 1501—1505

Aftercare After removal of the cast an Unna's paste dressing is applied from the webs of the toes to the knee (see Verbandlehre, pp 70—84) In addition arch supports with a high outer edge are prescribed

Massage and passive motion must be avoided, because they may even after many months lead to flare up and progression of the inflammation

No exercise should produce pain (see Vol I/p 45)

Treatment of Pes Equinus

If the ankle joint is not stiff a traction splint can be applied as in figure 2780 Otherwise an oblique subcutaneous tenotomy of the Achilles tendon is carried out and the foot is dorsiflexed to the proper position In bony ankylosis a wedge is removed from the region of the talonavicular joint This operation may not be carried out until a half year after the last fistula has closed Both bones are held together with crossed Kirschner wires

After simple tenotomy of the Achilles tendon a walking cast is applied for 4 weeks After removal of a wedge of bone a walking cast is applied for 8 to 10 weeks

Treatment of Contractures of the Toes

In *plantar contracture of the great toe* the base of the proximal phalanx is removed More than half of the phalanx should be removed

In hammer toe formation of the second to fifth toes the head of the proximal phalanx should be removed through a longitudinal dorsal incision which splits the extensor tendon No sutures or ligatures should be buried

Arthrodesis of the talar joints If painful arthroses occur in the talocrural, talocalcaneal or talonavicular joints the involved joints should be fused in the manner described on pages 1980—1988

Operative Treatment of Traumatic Pes varus, cavus and planus

Club foot is treated in the same manner as in figures 2774—2779 For the treatment of pes cavus and flat foot appropriate wedges are removed from the foot The operation may not be carried out before six months after the last fistula has healed The bones are then held together with crossed Kirschner wires

if possible without removing the cast This is usually possible by enlarging the window

Secondary hemorrhages are rare in gunshot wounds of the talar joints If they occur one should not attempt to control them by pressure alone but should ligate the spurting vessel

Removal of Missiles During the first 3 months they should only exceptionally be sought if the wounds were not excised If they are found at the opening of abscesses they are removed

Treatment in a Walking Cast In aseptic gunshot wounds of the talar joint a walking cast can be applied after 3 weeks In infected gunshot wounds of the ankle it can be applied when the temperature has returned to normal and the wounds have become smaller Window edema should be avoided by careful technique in dressing (see p 2129) The usually advanced decalcification found in gunshot wounds of the ankle can be largely avoided by weight bearing in plaster This however should never cause pain

Roentgen Check In aseptic gunshot wounds of the ankle with marked displacement that are treated by continuous traction, fresh roentgenograms should be obtained every 2 weeks In infected cases they are made only at the time of cast change, after cast removal and at the close of treatment

Avoidance of Flail Joints A flail ankle joint renders the leg practically useless Since this only occurs after joint resections these must be avoided

Avoidance of Disturbances of Mobility Good mobility can only be achieved if there is no significant involvement of the joint surfaces and no infection The attempt to avoid them by early motion always leads to a bad result If the joint surfaces are partially destroyed, and if some mobility remains weight bearing is usually painful Therefore bony ankylosis in good position is the result to be sought in infections

Pes equinus, club foot flat foot and pes cavus can always be avoided if the immobilizing cast is applied properly and immobilization is continued until the bones have healed

Flexion contractures of the toes cannot occur if the cast extends forward to the tips of the toes on the plantar surface and the patient carries out appropriate exercises

Advoidance of Flexion Contractures of the Knee Joint These only occur if the patients walk with crutches without plaster immobilization and flex the knee to avoid tripping over the drop foot

Exercises In the aseptic cases the toes are actively moved from the first day on In infections this should be deferred until the high fever abates If paralysis is present the patient is supplied with individual slings for his toes and with these he hyperextends his toes In addition a piece of foam rubber or cellulose is placed under the toes on the foot plate of the cast This holds them elastically in slight dorsiflexion and they can be actively flexed against this resistance

The thigh muscles must be actively tensed

If the patients are required to remain in bed for a prolonged period the sound leg is exercised on the mountain climbing apparatus (see Vol I/figs 21, 22) In addition the patient carries out other exercises with his sound leg

Course of Gunshot Wounds of the Talar Joints and Results of Treatment

Mortality Jimeno Vidal (see p 2125 footnote) did not lose one of his 238 patients In the Franco German war the mortality was 30%, in the first World War 1 to 2%

Amputations Vidal also did not perform any amputations, while in the Franco German war 29 8% and in the Boer war 26 8% came to amputation



2982 July 23 1936 2983



2984 October 12 1936 2985

Figs 2982 2983 —Complete outward and upward dislocation of the forefoot in Lisfranc s joint Sustained by a 29 year old technical worker in a 30 M fall with a glider

Figs 2984 2985 —Same case after 11 weeks All bones are in their proper place Calcium content markedly reduced Mobility normal Pain on walking





2978 May 26 1917 2979

Fig 2978—Divergent dislocation of the metatarsals The first metatarsal is displaced inward while the second to fifth are displaced laterally The first cuneiform projects between them like a wedge The foot is markedly widened and shortened

Fig 2979—Sam case from the side The first metatarsal is not only displaced medially but also plantarward and the second to fifth are not only displaced laterally but also dorsally





2980 May 26 1917 2981 July 24 1917

Fig 2980—Same case Exposure obtained at a rotation of 45° By this maneuver the double divergence is especially well demonstrated

Fig 2981—Same case after 8 weeks All joints have healed in good position These roentgenograms have been taken from my publication (see footnote p 2136)



2990 April 29, 1937 2991



2992, July 10 1937 2993

Figs 2990 2991 —Lateral and plantarward dislocation of the base of the fifth metatarsal in relation to the fourth and the cuboid Sustained by a 33 year old lod smith who caught his foot between a wagon and a street car track Reduction and walking cast for 5 weeks

Figs 2992 2993 —Same case after 10 weeks Healing in good position with complete recovery of function

Functional Results The ankle joint was involved 151 times 76 patients (50 3%) had ankylosis in good position, 49 (32 5%) had normal mobility and 26 (17 2%) had limited mobility

The talocalcaneal joint was involved 132 times 105 patients (79 6%) had ankylosis in good position, 7 (5 3%) had normal mobility and 26 (15 3%) had limited mobility

My results are given in Vol I/p 206



2986 September 24 1937 2987



2988 November 11 1937 2989

Figs 2986 2987 — Open inward and downward dislocation of the first metatarsal Minimal outward displacement of the second through fifth metatarsals Large transverse contused laceration over the entire dorsum of the foot with wide opening of Lisfranc's joint It is markedly soiled Sustained by a 24 year old nurse who was run over by an automobile

Figs 2988 2989 — Same case after 2 months All bones are in normal position The wound has healed with a soft narrow pliable scar It had been carefully excised The soiled bone was cleaned with a chisel Then the skin was sutured without burying sutures or ligatures Reduction of the dislocation and application of a cast which was immediately split Exposed treatment of the wound 14 days after injury walking cast for 6 weeks

web strap is laid over this and a 5 kg weight suspended (fig 2972) When after several minutes the foot becomes narrower and longer the swelling is pressed away vigorously with both hands and the displaced bones are pushed back into their joints Sometimes it is necessary again to bend them over a wooden wedge or a padded table edge after shortening has been corrected

Roentgen Check When one has seen on the image intensifying screen that reduction has been successful, roentgenograms are obtained from both sides

Placement of the Crossed Kirschner Wires Since these dislocations are un stable after reduction, crossed wires are introduced so as to maintain them in good position (figs 2993 a b)

Roentgen Check After placement of the wires new roentgenograms are obtained from both sides

Immobilization in Plaster When the roentgenograms show good reduction with good position of the wires, the web belt with the quilted pad are removed from the leg and the finger traps or traction bandage from the toes A temporary short leg cast is then applied (see pp 1917—1927), which is immediately split through the last thread

Application of the Short Leg Walking Cast The short leg walking cast is applied after the swelling has receded, usually after 8 to 10 days in the manner described on page 1926

Duration of Immobilization and Removal of the Crossed Wires The walking cast is removed 6 weeks after the injury If the skin is in satisfactory condition, the wires can be removed at this time, otherwise they can be removed after a few days when it is entirely clean

Roentgenograms, exercises and further treatment are carried out as for malleolar fractures (see pp 1930, 1931)

Treatment of Dislocations of the First or Fifth Metatarsals

Reduction and immobilization are carried out in the same manner as fracture dislocations of the first metatarsal (figs 2993 a—d) using finger traps and traction bandages and fixing them with crossed wires The use of crossed wires is especially necessary for the fifth metatarsal as it is always unstable after reduction

FRACTURE-DISLOCATIONS OF THE FIRST METATARSAL

Mechanism They are incurred by falling on the head of the first metatarsal while the ankle is plantarflexed and the toes are dorsiflexed The lateral half of the base of the first metatarsal is sheared off and dislocated medially and centrally as in a Bennet s fracture-dislocation of the first metacarpal (figs 1289 to 1301)

Reduction and immobilization are carried out as for dislocations of the first metatarsal The fracture-dislocations are especially unstable and must therefore be fixed with crossed wires (figs 2993 c, d)

127 SPRAINS OF THE TARSAL AND METATARSAL JOINTS

Sprains of the joints of the tarsal and metatarsal joints occur frequently and result from direct and indirect trauma They can be so mild that the pain

What Questions Should We Ask Ourselves in Order to Avoid Failures in the Treatment of Gunshot Wounds of the Talar Joints?

They are the same as for the treatment of infected tibiofibular shaft fractures (see p 1797) Because of the traction the questions of pages 1715 and 1718 should be included and because of the long leg cast those of page 1735

126 DISLOCATIONS IN LISFRANC'S JOINT

Mechanism Dislocations in Lisfranc s joint are usually incurred in a fall on uneven ground or in being run over

1 Case History I once saw a case of divergent dislocation which resulted when a man jumped out of a window on a street paved with round stones (so called cat s heads) (Figs 2918—2980) [1]

2 Case History Another time a mechanic was kneeling under a car while working This car had been raised by means of a jack which gradually gave way and the weight of the car came to rest on the heel while the forefoot was vertical on the heads of the metatarsals In this way the cuneiforms were driven between the metatarsals like a wedge and forced them apart

The *displacements* are manifold The commonest is the outward and upward (lateral-dorsal) dislocation of all the metatarsal bones (figs 2982 2983) Divergent dislocation in which the first metatarsal is dislocated inward and downward and the other four outward ond upward is much less common (figs 2978—2980) In addition there are outward and upward dislocations of the second to fifth metatarsals, while the first remains in its normal position There are also dislocations of only the first or the fifth metatarsal bones The first is usually displaced inward or inward and downward (figs 2986, 2987), while the displacement of the fifth is usually plantarward (fig 2991)

Clinical Diagnosis In the first few hours before the appearance of swelling the change in form can be readily seen The dislocated base of the metatarsal is under the skin and can be seen as a bulge The skin is here often white and ischemic The patient of figures 2978—2980 told how the dislocated bones on the dorsum of the foot had looked like a wreath Later the foot swells markedly and they can only be palpated and no longer seen In dislocations of all five metatarsals the foot is widened ond shortened

Roentgenologic Diagnosis In order to demonstrate the displacement oblique exposures (fig 2980) should be obtained in addition to the dorso plantar (fig 2978) and lateral (fig 2979) exposures because the extent of the displacement is otherwise not fully brought out

Treatment of Dislocation of All Five Metatarsals

Reduction If the displacement is not great and no significant shortening is present, one may attempt reduction over a wooden wedge (fig 2816) or over the padded edge of a table under local anesthesia

If reduction is thus not possible, the five toes are supplied with finger traps or traction bandages and the foot is suspended by these from a trans verse bar The quilted cellulose pad is placed above the ankle joint A 50 cm

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1 Bohler L Über einen Fall von divergierender Verrenkung der Mittelfußknochen Zbl Chir *44* 1083—1085

appeared they can thus be most readily reversed (Vol I/figs 35—38 and case histories Vol I/pp 48, 49)

I have often contended that injuries would heal much more rapidly if no physico therapy were carried out This is illustrated by the complications described in Vol I/pp 48—50 following the use of these measures in injuries of the foot



2993 c November 22 1955 — 2993 d January 23 1956

FIG 2993 c —Fracture dislocation of the first metatarsal (Bennett s fracture dislocation of the foot) Sustained by a 47 year old merchant who weighed 75 Kg and was 162 cm tall when he fell 2 M from a ladder on the strongly plantar flexed foot The fibular side of the base of the first metatarsal remains in position The tibial portion is sheared off The first ray is displaced tibially dorsally and centrally

FIG 2993 d —Same case two weeks after removal of the cast The first metatarsal has been so well reduced, that nothing remains to be seen of the fracture or of the dislocation It is fixed to the second metatarsal with two crossed wires Marked decalcification *Treatment* Reduction using a finger trap (fig 2972 a) was easily carried out Temporary cast which was split Since the roentgen check showed redisplacement after 5 days the great toe was again suspended by a finger trap in local anesthesia and the fracture dislocation again reduced Then fixation with two crossed wires and walking cast with which he was able to walk without a cane in 2 weeks without pain Removal of the cast 7 weeks after the injury and of the wires 2 weeks later Unna s paste dressing It took 5 months before he was free of pain and could walk normally The calcium content did not return to normal until after 7 months apparently because reduction was carried out twice

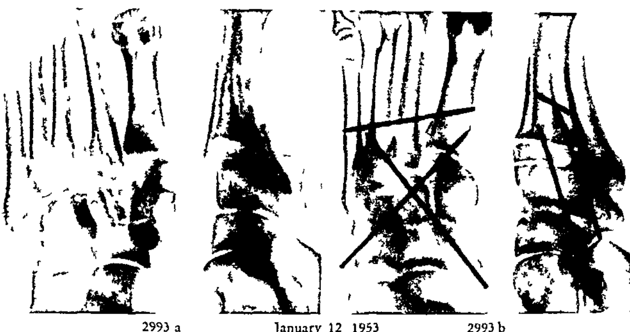
The only measure required in injuries of the foot is uninterrupted immobilization of the injured parts after good reduction Freedom from pain and elimination of all injurious reflexes are thus achieved and at the same time it becomes possible to use the injured leg without restriction Thus circulation is improved leading to active healing of the injured tissues

128 CLOSED METATARSAL FRACTURES

Mechanism Fractures of metatarsal can be produced by direct trauma i e by being struck by a heavy falling object, by being run over or by crushing injuries They are commonly open In addition they may be produced by indirect trauma as in a misstep or after prolonged strenuous marches (so called march fracture) All five bones may break at the result of direct trauma In

disappears after a few minutes, or permanent damage may be produced by stretching or tearing of ligaments Small avulsions of bone are often seen at the insertions of ligaments in severe sprains

Treatment If the foot is only slightly swollen and slightly painful an Unna s paste dressing is adequate If pain is severe at rest and especially on weight-bearing, a walking cast should be applied for 3 to 5 weeks The pain then disappears immediately and the much feared dystrophy with decalcification does not occur Some try to treat it with all sorts of measures and



2993 a January 12 1953 2993 b

FIG 2993 a—Subluxation of all five metatarsals in Lisfranc s joint toward the fibular and dorsal side with fracture of the bone of the second metatarsal Gap between second and third metatarsals Sustained by a 33 year old 168 cm tall woman who weighed 56 Kg in a fall over a stair in which she fell on the left forefoot

FIG 2993 b – Same case The forefoot was first reduced over a wooden wedge and then placed in the screw traction apparatus The bones were fixed to one another with three Kirschner wires Then a temporary cast which was split Three weeks after the injury a short leg walking cast Removal of wires 6 weeks after the injury Walking cast removed and Unna s paste dressing applied 10 weeks after the injury At removal of the walking cast strikingly minimal decalcification After 4½ months all joints freely mobile No complaints These roentgenograms are from Jorg Bohler Linz

medico-mechanical and physical therapy such as massage, passive motion, under water therapy short wave therapy diathermy, heated air, cooling also administration of calcium products and injection of elitysan and other presumably callus promoting drugs Others perform periarterial sympathectomy

The decalcification always results from the joint irritation reflex This is repeatedly set into action by weight bearing without plaster immobilization, by passive motion massage, over heating and cooling The best measure to combat pain and thus eliminate these injurious reflexes with their disturbances of circulation is complete uninterrupted immobilization in a non-padded cast With this the patient is at once free of pain and able to walk and thus weight-bearing is resumed and dystrophies can be avoided or if they have already

fractures the fracture line is so fine, that it can only be seen with the aid of a loupe If new roentgenograms are obtained after two weeks a wide fracture line is now evident as the result of resorption (figs 2994, 2995)

Local anesthesia If severe swelling and pain are present the fracture site is anesthetized by the injection of 20 cc of 2% Novocain solution



2996 September 17 1929



2997 March 27 1930

Fig 2996—Large painful ball callus after fracture of the second and third metatarsals 10 weeks after the injury Sustained by a 22 year old patient when a 30 kg piece of iron fell on him The patient was treated from the beginning with massage passive motion baths hot air diathermy and infrared light without immobilization He walked with crutches for 6 weeks and for 4 weeks with two sticks The foot was still markedly swollen after 10 weeks He was not able to walk without a stick until after a year

Fig 2997—Same case six months after injury The callus has decreased around both fractures Because of the persistent intensive treatment the periosteal reaction extends over the entire shaft

Immobilization Since the entire weight of the body presses on the fractured bone bending it with every step, the foot without a cast is painful and swells for a long time In order to relieve the fracture site and immobilize it the hematoma and the swelling are pressed away and a non padded temporary short leg cast is applied as for malleolar fractures (see pp 1917—1927) The longitudinal and transverse arches are carefully molded After the swelling recedes namely after 6 to 8 days, it is replaced by a short leg walking cast (see p 1928)

Duration of Immobilization In fractures of the first metatarsal immobilization should be continued for 6 weeks in those of the second and third for 5 weeks If the cast is removed after this time the fracture site is no longer tender to pressure or on weight bearing In the roentgenogram the callus formation is only modest (fig 2995)

indirect trauma usually the second or third is fractured in the shaft or the fifth at the base

Displacements In those fractures of the second and third metatarsals resulting from indirect trauma there is usually no displacement There is usually a separation of the fragments in avulsion fractures of the base of the fifth metatarsal (figs 3008—3016)

Possible Complications of Metatarsal Fractures If these fractures are not treated adequately, prolonged disability and persistent edema lasting up to a year may follow even those without displacement Since in the absence of a cast the peripheral fragment is bent dorsally with every step, large callus masses are formed, that become even larger if the periosteum is repeatedly irritated by massage and passive motion (fig 2996) In fractures with displacement the arched structure of the foot is destroyed and if they are not exactly reduced permanent disability results



2994 December 19 1929



2995 January 31 1930

Fig 2994 —Fracture of the second and third metatarsals Slight lateral displacement is seen at the second Only a fine fissure can be seen on the third Sustained by a 28 year old man when an iron post fell on his foot

Fig 2995 —Same case after 6 weeks Both bones have healed in good position with thin periosteal callus which bears weight well A broad zone of resorption which is especially striking at the third metatarsal which showed only a fine fissure immediately after injury Treated by walking cast for 6 weeks The patient could walk without pain beginning the first day and had only minimal complaints after removal of the cast 10 weeks after the injury he was able to walk moderate distances without pain All joints were freely movable

Treatment of Metatarsal Fractures Without Displacement

Clinical Examination If roentgenograms are obtained from in front and from the side, one is surprised that no fracture line is evident Especially march

Roentgen Check When one has determined by fluoroscopy that no displacements remain, roentgenograms are obtained in both main planes while traction is continued One must be especially careful that no gap is present between the fracture ends as delayed callus formation, pseudarthroses and dystrophies may then result

Placement of the Crossed Wires When the fragments are in good position (figs 3002, 3003), and no gap is present between the fracture ends, two to three crossed wires are drilled through the metatarsals under observation with the image intensifier similar to those shown in figures 2993 a and b They must unite the central fragments with the peripheral fragments

Roentgen Check after Placement of the Crossed Wires If fluoroscopy shows good reduction of the fragments and good position of the wires, roentgenograms are made in both main planes

Application of a Temporary Short Leg Bed Cast If the roentgenograms show good position, a temporary short leg bed cast is applied in the manner described on pages 1917—1927 This is immediately split including the last thread The leg is placed on a Braun splint

Application of the Short Leg Walking Cast After the swelling has subsided, namely after 8 to 10 days, a short leg walking cast is applied in the manner described on page 1928

Duration of Immobilization Depending on the degree of displacement the cast is removed 8 to 10 weeks after the injury

Removal of the Crossed Wires If the skin is in good condition and the wires can be palpated through the skin, they are removed under local anesthesia with a sterile needle holder through a small incision immediately after removal of the cast If the skin is not entirely clean and healed, skin care is administered for several days until one can remove the wires

The *application of the Unna s paste dressing, exercises and further treatment* are carried out as for malleolar fractures (see pp 1930, 1931)

Duration of treatment Depending on the severity of the injury and the age of the patient 4 to 6 months are required for the symptoms to disappear

Reduction with Wires through the Pads of the Toes If it is not possible to achieve reduction with finger traps or traction bandages, the pads of the toes are anesthetized with local 2% Novocain infiltration Then the pointed 0 5 mm wires are placed through the toe pads After these are threaded through the small wooden spreaders that have holes through both ends, they are twisted together and attached to the round dowel An assistant then exerts *appropriate* traction manually (fig 2998) and presses the swelling away between both hands with vigorous pressure If the fracture sites are not too near the metatarsophalangeal joints (figs 3000 3001), the foot is suspended as in figures 2972 and the bones are fixed with crossed Kirschner wires

Application of the Toe Traction Cast

If the fracture sites are near the metatarso phalangeal joints (figs 3004 3005) and the roentgenogram shows good *position* the transverse dowel is suspended as *in fig* 2171 Then a cast is applied with the toes under continuous traction in the manner described in pages 1917—1927 The longitudinal and

Application of the Unna paste dressing, exercises and further treatment are carried out as for malleolar fractures, i e, with Unna s paste dressings and inlays (see pp 1928—1931)

Massage and Passive Movement If these fractures are treated with massage and passive movement and the patient is allowed to walk without plaster immobilization after a short time, the foot begins to swell and a large ball callus forms which is tender to pressure This remains palpable for months as a hard swelling on the dorsum of the foot Walking is then impeded for up to a year

Case History A case with especially severe complications should be presented A man slipped while going downhill and immediately experienced severe pain in the forefoot On the basis of the circumscribed tenderness to pressure, impaction and traction pain the diagnosis of fracture of the third metatarsal was made and treatment was begun with massage Since symptoms were still present after 4 months a roentgenogram was obtained for the first time This showed a periosteal reaction along the entire shaft of the third metatarsal similar to that in figure 2997 Nothing could be seen of the original fracture Since no bone atrophy was present, the diagnosis of luetic periostitis was made When his wife heard of this, she sued for divorce

Treatment of Metatarsal Fractures with Displacement

If fractures of the metatarsals heal with displacement the arch of the foot is usually disrupted and severe persistent disturbances of gait result Therefore the displaced fragments should be accurately reduced and then continuously immobilized until they are healed During this period the toes should be actively moved as far as possible

The same materials are required for *reduction* and *treatment* as for a fracture-dislocation of the navicular (see p 2121)

Time of Reduction If circumstances permit, it is best to carry out reduction at once If this is not possible, it is necessary to wait 6 to 8 days until the swelling has largely receded In the meantime the leg is placed on a Braun splint with the forefoot suspended by a triangular bandage (fig 2641) If there is no skin damage a pressure dressing can be applied with sponge rubber, but pain from pressure of the bandage should not be allowed to occur

Local Anesthesia At every fracture the fracture site is rendered anesthetic by the injection of 2% solution of Novocain

Reduction with Finger Traps or Traction Bandages After the original roentgenograms and not sketches are so placed that the surgeon can readily see them during reduction finger traps or traction bandages are placed on the toes and fastened to a transverse bar The 0 5 × 10 × 18 cm pad is placed above the ankle and a 5 Kg weight is suspended by a 50 cm web strap placed over this Sometimes a great weight is necessary (fig 2972) The strap is spread with the 25 cm board for the application of the cast (fig 2998) The swelling is pressed away by vigorous compression between the surgeons hands When after 4 to 5 minutes the shortening and thickening of the forefoot produced by the displacement of the fragments disappears, the still displaced fragments are forced into alignment by vigorous pressure until the step between the bones can no longer palpated



3000 September 26 1931 3001

Figs 3000 3001 Fractures of the first to fourth metatarsals and avulsion at the medial side of the base of the proximal phalanx of the fifth toe The distal fragments are markedly medially displaced The first is in varus of 40° with a dorsally open angle of 50° Compare fig 2998



3002 November 31 1931 3003

Figs 3002, 3003 —Same case after 10 weeks All bones have healed in good position with vigorous callus After 4 months walking is painless All joints are actively freely mobile No swelling Age 46 years Treated in plaster immobilization with traction on the toes for 4 weeks Then 3 weeks walking cast Later Unna s paste dressing and arch supports No massage



2998 September 26 1931

Reduction of a fracture of the first to fourth metatarsals 8 days after the injury the 4 metatarsals and their corresponding toe pads were locally anesthetized Then *stainless steel* wires were drawn through the toe pads and supplied with small spreaders and a common dowel Traction was exerted on these while counter traction was afforded by a padded web strap which was applied above the ankle joint Compare the roentgenograms belonging to this case (figs 3000—3003) Traction bandages about the proximal phalanges can be used instead of wires through the toe pads



August 3 1928

Fig 2999—Device used in treatment of displaced fractures of metatarsals or toes Stainless steel wires are placed through the toe pads Then the fractures are reduced by forceful longitudinal traction and an unpadded plaster cast is applied over this The traction cords are fastened to a stirrup the sides of which are of wood so that the lateral roentgenogram is not obscured by metal Because bone atrophy and limitation of motion of the toes can follow strong traction we now usually utilize crossed wires to maintain the position of the reduced fragments as in fig 2993 b

Operative Treatment of Metatarsal Fractures with Displacement

In transverse fractures with displacement by the full width of the shaft and shortening it is sometimes not possible to achieve reduction by traction on the pads of the toes In these cases the fractures are exposed in local or general anesthesia and under tourniquet ischemia In the open wound it is usually easy to reduce the fracture If only one bone was broken the reduction remains stable If several bones are broken as in figures 3000, 3001 and 3004, 3005, a hole is drilled into the bone near the fracture and a Kirschner wire is



3006 3007

FIGS 3006 3007 —Same case after 10 weeks Bones and joints show good position *Minimal angulation* with a dorsally open angle is present at the third metatarsal Bony healing with *delicate callus* Reduction under local anesthesia with wires through the toe pads See fig 2998 Immobilized in plaster with continuous traction (*see fig 2999*) *for 4 weeks followed* by a walking cast for 3 weeks then Unna s paste dressing arch supports never massage Walks well in 4 months Age 28

threaded into the medullary canal This prevents angulation and lateral displacement The operation is carried out on the first day before development of swelling or after the swelling has subsided *after 8—10 days* Then a temporary cast is applied and immediately split, followed by a walking cast for 4 to 5 weeks

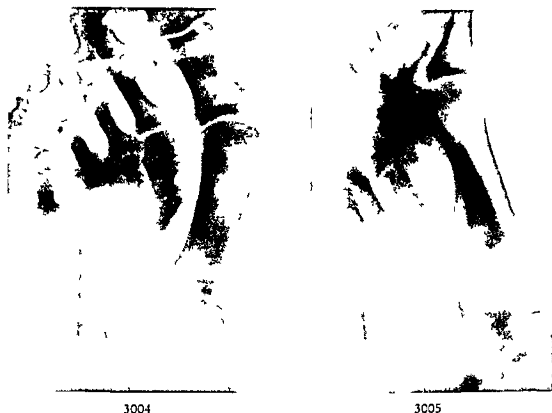
Treatment of Avulsion Fractures at the Base of the Fifth Metatarsal

Mechanism These fractures usually result from slipping off of the sidewalk or other elevation or by turning one s ankle *namely* by sudden strong contraction of the peroneus brevis muscle (figs 3008—3016)

transverse arches are continuously molded until the cast begins to get hard Then the sling with the traction is removed and the pad is enclosed by the third circular plaster bandage The stirrup with the wooden pieces is then attached, and the wires are fastened to this (fig 2999)

Splitting the Cast If the reduction is carried out on the first day the cast must be immediately split If on the other hand reduction is not carried out for several days, it is usually not necessary to split the cast

Placement of the Leg The leg is placed on a Braun splint with the cast and extension apparatus and rotation is prevented by suspending the toe plate of the cast from the Braun splint



3004 3005

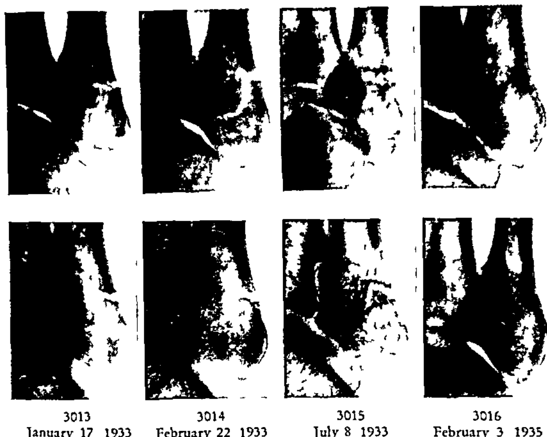
Figs 3004 3005 —Fracture of the second and third metatarsals near their heads Avulsion at the base of the fifth metatarsal and subluxation at the base of the fourth Dislocation of the fourth and fifth toes at the metatarso phalangeal joint and dislocation of the fifth toe in the distal joint with further displacement of the distal phalanx of the toe

Control of the Traction Since the joints of the toes are loosened by the traction the effectiveness of the traction decreases The traction ties must therefore be tightened 1—2 mm every 2 to 3 days

Roentgen Check Every week new roentgenograms must be obtained in both main planes

Duration of Immobilization in the Toe Traction Cast This cast should remain for 4 weeks Then a lower leg walking cast is applied for an additional 4 to 6 weeks *Further treatment* follows as for malleolar fractures (see pp 1930, 1931)

four weeks and a wide fracture space results This is bridged by filmy periosteal callus (fig 2995) In fractures with marked displacement that were accurately reduced the fracture line is much narrower after 6 to 8 weeks than in those without displacement (figs 3002, 3003, 3006, 3007) because the fracture ends are pulled together by muscle pull



3013 January 17 1933 — 3014 February 22 1933 — 3015 July 8 1933 — 3016 February 3 1935

FIG 3013 —Avulsion of the entire base of the fifth metatarsal sustained by a 48 year old patient who slipped on an icy walk while running He felt and heard a crack at the lateral margin of the foot Roentgenograms above obtained exactly from in front and those below slightly obliquely laterally

FIG 3014 —After 5 weeks Fracture space widened to double its width because of resorption

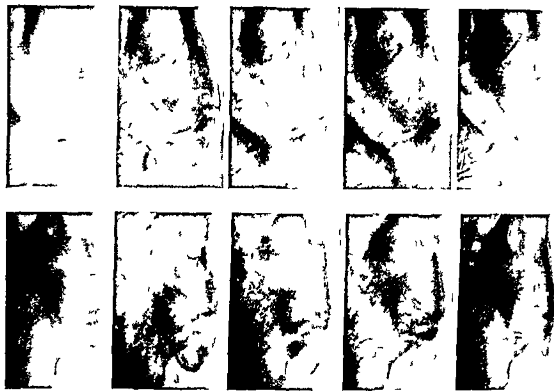
FIG 3015 —After 6 months Fracture surfaces sclerosed Fracture space even wider but filled with delicate callus

FIG 3016 —After 2 years Fracture line closed Only a fine bone scar to be seen on the lateral surface

In *fractures of the shaft of the fifth metatarsal* well developed periosteal callus never occurs, neither following immobilization nor early institution of massage regardless whether marked displacement has occurred as in figures 3017—3022 or whether minimal displacement occurred as in figures 3023—3028

In *avulsion fractures of the fifth metatarsal* the gap between the fragments is present immediately after the injury because of the mechanism involved (figs 3008, 3013) The gap between the fragments becomes larger in the next 2 to 12 weeks (figs 3009, 3010, 3014, 3015) and then again gradually decreases (fig 3011) It usually requires 10 to 12 months for the fracture line to be bridged by bone (figs 3012, 3016)

Treatment If severe pain is produced by weight bearing, a non-padded walking cast is applied for 3 weeks as for a malleolar fracture (see pp 1917—1928) followed by an Unna s paste dressing for 3 to 5 weeks (see Verband lehre, p 74—80) If symptoms are minimal an Unna's paste dressing may be applied at once



3008 January 7 1936 | 3009 February 7 1936 | 3010 April 7 1936 | 3011 Sept 29 1936 | 3012 Dec 28 1936

Figs 3008—3012 -Avulsion of the tip of the base of the fifth metatarsal Sustained by a 36 year old patient who slipped from the sidewalk The fragment is pulled 2 mm away from the main bone In the upper picture seen from in front in the lower obliquely from the side

Fig 3008 —On the day of the injury

Fig 3009 - After 4 weeks The fracture line has become smaller Both fracture surfaces appear sclerosed

Fig 3010 -After 3 months Beginning union on the lateral side

Fig 3011 —After 8 months Fracture cleft still present on the medial side but markedly narrowed

Fig 3012 —After 1 year Fracture line completely replaced by bone but still recognizable

Callus Formation in Metatarsal Fractures

Callus formation varies not only with the method of treatment but also with the metatarsal involved

If the fracture is not immobilized and in addition massage and passive motion are carried out, a large ball-shaped painful callus (fig 2996) develops in fractures of the second and third metatarsals even after simple fissures This persists for 6 to 12 months (fig 2997) If these fractures are adequately immobilized, resorption of the fracture surfaces takes place during the first two to

underwater massage for 6 weeks Since the roentgenogram showed no callus after 8 weeks intravenous calcium injections were given These were followed by X irradiation and Elityran She was required to use two canes to avoid the danger of breaking the bone by too firm weight bearing Calcium metabolism was investigated and found to be normal I saw 12 weeks *after the injury* Limping gait with two canes The dorsum of the foot was swollen and the calf of the involved foot showed 2 cm atrophy The fracture cleft was still wide (fig 3023 3024) I had her elevate the leg The swelling disappeared by the next day Then an Unna s paste dressing was applied She was able to walk with this and without a cane as soon as she heard that the bone was so well healed that there was no danger of refracture 9 weeks later *symptoms had disappeared The roentgenogram* (figs 3025 3026) showed that the fracture cleft had begun to close but not because she did not receive callus forming remedies but because visible callus does not appear in these fractures before 4 months After 6 months (figs 3027 3028) the fracture cleft was largely closed



3023 3024 October 5 1931 3025 3026 November 4 1931 3027 3028 January 15 1932

Figs 3023 3024 —Torsion fracture of the fifth metatarsal with minimal displacement 12 weeks after injury Sustained by a 26 year old white woman while dancing Calcium content slightly reduced Fracture space still wide open

Figs 3025 3026 —Same case after 4 weeks Delicate callus in the fracture space

Figs 3027 3028 —Same case after 3 months namely 6 months after the injury Fracture space bridged by bone

When such overzealous treatment is used one often hears that newly developed measures have been utilized and have led to healing in cases with delayed calus formation I have sometimes had the impression that so much new research would not be necessary if simple understanding of the normal course of callus formation were present

129 OPEN FRACTURES OF METATARSALS

Mechanism These fractures usually occur from direct trauma as from being struck by heavy objects, from being run over or from crushing injuries The severe damage to the skin and soft tissues with bleb formation and skin necroses are often of *primary importance*

Wound Treatment If the patient is admitted within the first 6 hours, the wounds should be thoroughly excised in the manner described in Vol I/pp

It is important to be aware of this variation in callus formation in fractures of the different metatarsals in order to protect the patients from over zealous treatment and incorrect diagnoses (see case history p 2142) The following case histories show that physicans and their families suffer particularly as a result of ignorance in this regard



3017 3018 October 7 1935 — 3019 3020 January 10 1936 — 3021 3022 July 23 1938

FIGS 3017 3018—Torsion fracture of the fifth metatarsal with a medial torsion wedge Lateral displacement and angulation with a laterally open angle Sustained by a 24 year old motorcyclist in a collision with an automobile

FIGS 3019 3020—Same case after 3 months Angulation corrected Lateral displacement still present Bony union of the torsion wedge with the two main fragments Otherwise the fracture cleft remains wide open

FIGS 3021 3022—After 2½ years Fracture space bridged by bone

1 *Case history* A 24 year old woman physician sustained a typical avulsion fracture of the base of the fifth matatarsal in slipping off a rock Immediate roentgenogram showed the slightly gaping fracture cleft The foot became markedly swollen on its lateral margin After 4 days she was given a cast with which she remained in bed for 10 days At cast removal a new roentgenogram was obtained This showed a widening of the fracture cleft Thereupon various callus stimulating drugs were administered such as Vigantol and pro ossa in addition to a special diet As new roentgenograms 4 weeks after the injury showed further widening of the fracture cleft and beginning decalcification removal of the fragment was suggested to her by one surgeon and screw fixation by another

When I saw her in the sixth week the foot was slightly swollen and she walked with a limp These symptoms disappeared after two weeks treatment with an Unna s paste dressing

2 *Case history* A very well known roentgenologist turned his ankle He felt and heard a crack at the outer margin of his foot A roentgenogram showed the ordinary avulsion fracture at the base of the fifth metatarsal with the gaping of the fragments The foot was wrapped with an elastic bandage Every week new roentgenograms were made which showed increasing width of the fracture cleft He was therefore very concerned and came to me in the 8th week because he felt very weak in his foot When I told him that this was the normal course he no longer limped

3 *Case history* The 26 year old wife of a naturalhistory professor slipped while dancing and sustained a torsion fracture of the shaft of the fifth metatarsal (fig 3023) Her father and her father in law were physicians She was given a starch bandage for 5 days followed by massage short wave therapy and pro ossa Because the foot remained swollen she was given

FRACTURES OF THE SESAMOIDS OF THE GREAT TOE

Isolated fractures of the sesamoids occur but are rare Bipartite or "split' sesamoids should not be mistaken for fractures The fractures show sharp fracture surfaces while the "split sesamoids have smooth edges

For treatment a walking cast is applied for 4 weeks as for a malleolar fracture (see pp 1917—1927) The patients can then immediately walk without pain If pain persists for months in spite of immobilization, the fragment should be removed (fig 3028 c) Further treatment Unna paste boot (see Verbandlehre, pp 70—84) and sometimes arch supports

130 DISLOCATIONS OF THE TOES

Among the 14 joints of the toes dislocations of the distal joint of the great toe are the commonest (figs 3029, 3030) Dislocations of the metatarso-phalangeal joints are relatively common Several toe joints may be dislocated simultaneously (figs 3000, 3005)

Reduction In closed dislocations reduction is usually easily accomplished by quick pull and pressure Often no anesthesia is necessary In open dislocations the wound must first accurately be excised according to the rules in Vol I/pp 149—174

Immobilization After dislocations in the metatarso-phalangeal joints it is best to apply a short leg walking cast for 3 weeks In dislocations of the interphalangeal and distal phalangeal joints a strip of adhesive tape is sufficient to maintain good position This can be applied around the joint in three to four layers after the swelling has receded If the dorsum of the foot swells an Unna s paste dressing is applied (see Verbandlehre, pp 70—84) to the foot and leg

METATARSO-PHALANGEAL JOINT SPRAINS OF THE GREAT TOE

Sprains of the metatarso-phalangeal joint often lead to persistent painful swelling if they are not immobilized

If the symptoms do not disappear after the application of several adhesive tape strips and an Unna s paste dressing, a plaster splint is applied from the arch of the foot to the tips of the toes

In old injuries a steel support is built into the medial side of the sole of the shoe so that the joint cannot be dorsiflexed with every step when the patient walks This support can also be used in fresh injuries

131 FRACTURES OF THE GREAT TOE

Mechanism These fractures usually are incurred when a heavy object is dropped on the toe or in being run over They are common in heavy laborers We have seen not less than 670 cases in the two years 1948—49 Of these 548 involved the terminal phalanx and 122 the proximal phalanx Of the latter 19 were open Zrubecky [1] reviewed the 122 cases of fractures of the proximal phalanx and reexamined 83 of the patients (68 4%)

[1] Zrubecky Brüche der Großzehe deren Behandlung und Behandlungsergebnisse Arch orthop u. Unfallchir 47 591—611

149—174 Then the skin and the skin only is sutured without burying sutures or ligatures If the muscles are damaged, a drain is inserted for 24 hours If the wound is older than 6 hours it may be excised but must be left open

If the soft tissues are so damaged that very large skin defects are present, it is usually best to amputate the injured parts of the foot at a level which allows good coverage of the stump with plantar skin Covering extensive defects with pinch grafts, as has often been very satisfactory in the hand and in the region of the malleoli, is not always to be recommended in the foot It is especially unsatisfactory to use vitamin-containing or other ointments which are supposed to facilitate epithelialization without achieving satisfactory coverage with skin The healing time is thus markedly delayed and the result after many months is usually a very tender and relatively useless foot

Treatment of the Fractures The open fracture is converted to a closed fracture by thorough wound excision and suture of the skin It can be then reduced and further treatment carried out as for closed fractures

If the skin can only be closed with tension, no significant traction may be used for reduction or fixation as the wound might reopen and infection develop

The Time Factor in the Treatment of Open Fractures of the Metatarsals

In the presence of the severe damage to the skin and soft tissues, which follows direct trauma, healing of the fractures is often long complete by the time the skin has healed

Case history The 67 year old mother of a surgeon friend of mine wanted to repair something on a heavy chest that had a sharp projecting upper edge when it tipped over and fell on her forefoot She was treated with compresses Because the foot was painful and swollen she was brought to us after two days On the dorsum of the foot was an 8 by 1 5 cm white ischemic strip the edges of which were macerated from the compresses and somewhat inflamed The roentgenogram showed fractures of the first through fifth metatarsals without displacement

A non padded cast was immediately applied and windowed over the ischemic strip The pain disappeared a few hours after the application of the cast On the next day this strip turned brown and later black Dry necrosis of the skin had developed The surrounding area showed no evidence of inflammation After the 4th week my assistants often came to me to ask if they should remove the dried skin I did not permit this After 10 weeks a walking cast was applied with which the patient got up After 4 months the 8×1 5 cm strip of skin that was 4 mm thick fell away Good epithelium had developed under this When the cast was removed the ankle was immediately mobile through half its normal range A week later it was completely mobile and several weeks later no symptoms remained

What would have happened if the wet compresses had been continued? Moist necrosis of the skin would have developed and infection of the fracture site would have developed If the necrotic dry skin had been removed already after 4 weeks, an open wound would have been created and the fracture would have been converted from a closed one to an open one Early infection of the fracture sites and tendon sheaths could have developed Under any circumstances more or less severe pus formation would have occurred in the granulation tissue Healing and epithelialization would have required longer and the scar would not have been as good

To restrain physicians from using superfluous and injurious measures of treatment has always been a difficult problem

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Prevention of Fractures of the Toes With such a large number of fractures of the toes it was desirable to distribute shoes with hard toes of leather or metal in all occupations in which this was a hazard Curiously this suggestion was followed only by a few



3028 a — 3028 b — 3028 c

April 25 1955 — January 3 1956

Fig 3028 a —Metatarso phalangeal joint of the great toe with normal sesamoid with slight varus position of the toe The fibular sesamoid is displaced toward the fibula

Fig 3028 b —Metatarso phalangeal joint of the left great toe of the same patient as in fig 3028 a with a transverse fracture of the fibular sesamoid Sustained by a 42 year old roofer in a fall from the fourth story Otherwise he sustained only contusions and no other fracture The fragments have separated by 7 mm on the fibular side and 14 mm on the tibial side The periphereal fragment was tipped 90° fibularwards That this is a fresh fracture and not a bipartite sesamoid bone can be seen from the sharp edges of the fragments The parts of a bipartite sesamoid are never that far apart

Fig 3028 c —Both fragments of the fibular sesamoid have been removed because the patient always had pain on weight bearing After their removal the pain disappeared

Classification of Fractures of the Proximal Phalanx of the Great Toe

Zrubecky developed the following classification from the standpoint of treatment

Group 1	Subtrochlear fractures without displacement	37
Group 2	Subtrochlear fractures with the typical displacement, namely a dorsally open angle, with lateral displacement and rotation of the fragments (fig 3034)	39
Group 3	Shaft fractures	
	a) Without displacement	28
	b) Lateral displacement of the full width of the shaft and shortening	5
Group 4	Fractures at the base of the toe	7
Group 5	Unusual types	
	a) Fracture through the trochlea with dorsal tilting	3
	b) Dislocation and fracture	
	c) Fracture of the epiphysis	2
	Sum	122

Displacement of the Fragments More than half of these fractures are not displaced The rest show typical angulations with a dorsally open angle and sometimes even shortening, lateral displacement or rotation The dorsally open angle is produced by the pull of the extensor hallucis longus This tips the distal fragment dorsally, while the muscles that insert at the base of the proximal phalanx (adductor hallucis and flexor hallucis brevis) hold the central fragment in plantarflexion



FIGS 3029 3030 — Dislocation of the distal phalanx of the great toe toward the extensor surface before and after reduction

Technique of Roentgenography The following points must be observed in order to obtain good lateral roentgenograms of the foot (1) The foot should be placed with its medial side down on the cassette For this purpose a cushion should be placed under the medial aspect of the leg (2) The medial side of the great toe should touch the cassette This is especially important in hallux valgus (3) The remaining toes should be dorsiflexed with a loop of bandage, which is held by the patient (4) The central ray should be directed vertically at the distal joint

Possible Complications after Closed Fractures of the Proximal Phalanx of the Great Toe If a dorsally open angle of more than 10° remains, pain occurs on the plantar side of the toe on weight bearing

Possible Complications of open Fractures of the Great Toe If the wounds are not carefully excised and sutured wound infections develop If in the presence of extensive skin defects or in the presence of poor circulation the great toe is not immediately amputated, skin necroses occur and healing requires a long time

Avoidance of Complications Following Fractures of the Great Toe Pain after healing of the proximal phalanx of the great toe with angulation can be avoided by good reduction and adequate immobilization, and necrosis can be avoided by early amputation

Treatment of Closed Fractures of the Proximal or Distal Phalanx of the Great Toe without Displacement

When the swelling has subsided after several days, 3 layers of 1 cm wide adhesive tape strips are placed around the great toe for 3 weeks

Treatment of Closed Fractures of the Great Toe with Displacement

Reduction After local anesthesia the swelling is pressed away If shortening and lateral displacement are present, a muslin bandage is applied about the distal segment of the great toe and is fastened with skin adherent Then longitudinal traction is exerted with slight dorsiflexion in the metatarso phalangeal joint In this way the shortening is corrected Lateral displacement can then be corrected by lateral pressure Rotations are corrected at the same time The dorsally open angle is corrected by pressure on the distal segment with the index finger, while counter pressure is exerted with the thumb with the proximal segment in slight dorsiflexion In this position reduction can *usually be readily achieved because the long extensor is relaxed by the dorsi* flexion in the proximal phanlanx We formerly tried to forcefully bend the proximal and distal phalanges into flexion Reduction and immobilization could be achieved only with difficulty because the long extensor tendon was tensed in this position

Immobilization A 20 cm muslin bandage which has been folded until it is 1 cm wide is placed along the dorsum of the great toe and the first metatarsal Then a 6 cm × 15 cm plaster or cellona splint of eight thicknesses is placed on the flexor side of the great toe and the medial side of the first metatarsal *It is wrapped on with a moist muslin bandage* Until the plaster hardens the proximal phalanx is maintained in dorsiflexion and the distal in slight plantarflexion by exerting slight pressure on the extensor aspect of the head of the proximal phalanx and the distal phalanx while counterpressure is exerted on the plantar aspect of the proximal phalanx with the thumb

Roentgen Check After the plaster hardens, roentgenograms are made from both sides

Splitting the Cast If the roentgenograms show good position, the cast is split along the muslin bandage on the dorsum and the toenail is exposed in order that circulation may be observed

Placement The foot is placed on a Braun splint and suspended to prevent rotation

Application of a Walking Cast After 4 days new roentgenograms are obtained When these show good position, a lower leg walking cast is applied as for malleolar fractures (see pp 1917—1927)

If redisplacement has occurred, reduction is again carried out

Duration of Immobilization and Further Care The cast is removed 4 weeks after the injury Then an Unna's paste dressing is applied in order to prevent swelling of the dorsum of the foot

Operative Treatment of Fractures of the Proximal Phalanx of the Great Toe

In the presence of persistent displacement it is best to remove the head of the proximal phalanx

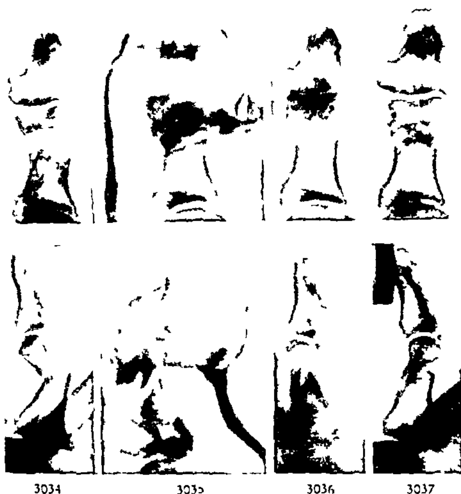
Callus Formation in Fractures of Toes

Callus formation in fractures of toes is usually strikingly scant or absent, similar to finger fractures (Vol I/p 973) In open comminuted fractures it sometimes takes up to 2 years before the fracture lines have been bridged

(fig 3038) One should not fall into the error of trying to fill this long period with callus stimulating measures

Treatment of Open Fractures of the Great Toe

The prognosis depends on the age of the patient, the circulation of the foot (dorsalis pedis and posterior tibial pulses) destruction of skin and the local circulation of the great toe



3034 3035 3036 3037
March 26 1936 April 24 1936 September 3 1936

FIGS 3034—3037 Fracture of the proximal phalanx of the great toe with typical displacement with dorsally open angle Above anterior and below lateral roentgenograms

FIG 3034—On the day of injury before reduction

FIG 3035—After reduction in plaster One can see clearly where the bending on the flexor surface must occur

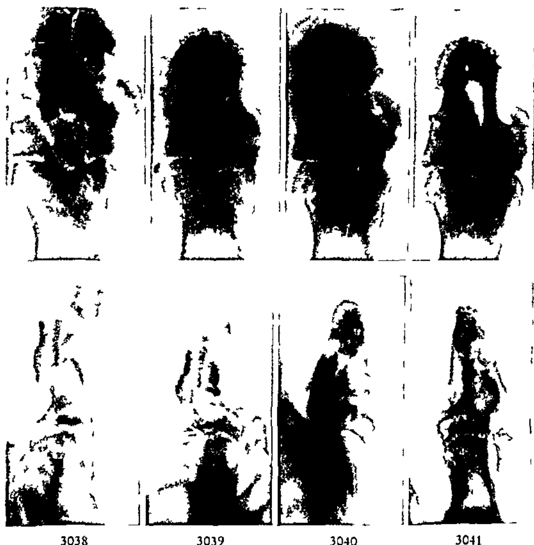
FIG 3036—After 4 weeks Firm healing Fracture line still visible

FIG 3037 After 6 months Fracture line bridged

If the pulses of the foot are absent the skin severely damaged and the toes blue, the toe should be amputated at once, the bone so shortened and rounded that it can be covered with good plantar skin Sometimes it is necessary to remove the head of the first metatarsal bone If not enough bone is removed, skin necrosis occurs and healing may take longer than a femoral

shaft fracture If one for instance learns that a 50 year old man dropped a 50 Kg weight more than 50 cm on his great toe, one can assume that his toe must be amputated without seeing the patient

Wound Excision If the skin is damaged only slightly, the wound can be excised according to the rules given in Vol I/pp 149—174 The skin is closed



3038 April 6 1936 | 3039 June 17 1936 | 3040 September 12 1936 | 3041 March 2 1938

Figs 3038—3041 —*Open* comminuted fracture of the distal phalanx of the great toe and fracture of the lateral condyle of the proximal phalanx Above anterior view below lateral

Fig 3038 —Immediately after injury

Fig 3039 —After 10 weeks Partial union of the fragments

Fig 3040 —After 5 months The proximal phalanx has healed with bony union Most of the fracture lines can still be seen

Fig 3041 —After 2 years All fracture lines have been bridged by bone In the middle a hole remains

after reduction of the fracture without burying sutures or ligatures Immobilization is carried out as for closed fractures The wound is left exposed beginning the second day

Application of a Walking Cast A walking cast may be applied after 2 weeks at the earliest

Infected fractures are best treated by bed rest until the wounds are healed, because these toes swell markedly on ambulation and then sometimes require months to heal

With this treatment in many hundreds of fresh as well as infected cases I have never seen inflammation progress to the metatarsus even though the joints and tendons were also involved

I have seen an open fracture of the distal phalanx of the great toe with which the patient was allowed to get up after eight days He was brought to us because of a progressive tendon sheath infection An amputation through the lower leg had to be performed because of sepsis

A report from Malgaigne shows how dangerous fractures of the great toe can be He writes that of 41 cases in the years 1836—1841 in the hospitals of Paris 7 died

With exact wound excision, good immobilization and antibiotics amputations at the lower leg and deaths can be avoided

132 FRACTURES OF THE SECOND TO THE FIFTH TOE

Mechanism These are produced in the same manner as are fractures of the great toe, namely by falling heavy objects or by being run over

Treatment In fractures of the middle and distal segments, application of adhesive tape strips after the swelling has receded suffices In fractures of the proximal segments a small sponge can be placed between the fractures toe and the neighboring toe and the two toes united with adhesive tape

In *open* fractures with severe skin damage amputation should be carried out at once If the skin is in good condition appropriate wound excision is carried out

GUNSHOT FRACTURES OF THE METATARSALS AND TOES

Treatment is carried out in the same manner as for the open and infected fractures of this region (see pp 2151—2159)

APPENDIX

Education, Organization and Economic Significance of Traumatic Surgery

Traumatic surgery has advanced considerably since the turn of the century As a result of the new methods in treating shock and of anesthesia many a life can be saved now which was formerly lost The general introduction of asepsis and primary wound excision markedly lessened the danger of wound infection A further reduction of the danger of infection has been accomplished by the use of antibiotics While formerly a compound fracture, or an open lesion of a joint often resulted in sepsis or death, this complication is very rarely observed at present Results of treatment have been remarkably improved since the introduction of X-rays and image intensification, skeletal traction, nailing of femoral neck fractures, intramedullary nailing, autogenous and homogenous bone grafting, osteosynthesis with Kirschner wires and the development of hand surgery

Improvement of our methods enable us in most cases to reduce a fracture accurately to maintain the good position until healing of the fracture has occurred and to obtain satisfactory use of the injured part by appropriate *painless* exercises

Statistics supplied by insurance companies and hospitals for traumatic surgery keep us well informed about early and late results of treatment

In spite of these advances, however, we still see many unsatisfactory results in traumatic surgery, as the importance of a systematic teaching program is not yet generally recognized because of poor organization at some places or because of the use of many improper therapeutic methods applied as a result of inadequate training of the physician or surgeon

In the following an attempt will be made to outline changes in our teaching and in our organization of traumatic surgery

Should these proposals be put into effect it is my conviction that the sum of 717 million D-Mark which had to be paid by German insurance companies in 1954 for treatment and compensations could gradually be cut to a third within a period of 5—15 years by means of more effective therapeutic results and shorter duration of our therapeutic measures

We do not fully realize the economic significance of traumatic surgery, until we consider that the number of accidents involving uninsured persons is much higher than those involving insured persons In the former we cannot determine the costs of treatment or the results of treatment

Improvements in traumatic surgerv will also favorably influence wartime surgery

Vienna, May 1957

LORENZ BÖHLER

I UNAVOIDABLE UNFAVORABLE CONSEQUENCES OF INJURY AND AVOIDABLE COMPLICATIONS OF TREATMENT

In my book I have pointed out many times that often complications following fractures and other injuries are not *inevitable results of accidents* but *avoidable results of treatment* That means they can be prevented!

Inevitable results of accidents and avoidable results of treatment A person is involved in a train accident and loses a leg This represents an *inevitable result of an accident* If a person however, sustains a minor wound on a leg and does not pay much attention to it or treats it with improper methods, or if poor organization of the ambulance-service and first aid prevents prompt admission to a hospital and therefore an amputation of the leg on account of sepsis is necessary, this represents an *avoidable result of treatment* and not an inevitable result of an accident In a closed fracture, shortening of more than 2 cm and angulation of more than 10 degrees usually can be avoided, if organization is satisfactory and treatment adequate Pseudarthroses following fractures of the neck of the femur, fractures of the carpal navicular or fractures of long bones are avoidable results of treatment and not inevitable results of accidents This also applies to various other conditions such as myositis ossificans with its consequent diminished mobility due to uncomplicated dislocations of the elbow and hip, stiffening or diminished mobility of fingers following closed fractures and other closed lesions of the carpus, forearm, elbow, upper arm and shoulder, stiffening or diminished mobility of the shoulder due to closed lesions of the elbow and the parts below the elbow, talipes equinus due to lesions of the leg and traumatic flat-foot due to malleolar fractures Progressive inflammations not localized to an open injury are also usually avoidable if organization and technique are adequate We could name many more examples

However all this should not lead to the conclusion that a physician should face legal consequences if an injury results in any one of the above complications or a patient loses a limb or dies due to wound infection, for the final outcome of an injury does not only depend on the physician s treatment It rather is the sum of all environmental factors which determine the final outcome It primarily depends on the teaching facilities, on the degree of the attending physician s training, then on the organization of first aid, the ambulance system, the social laws, the hospital system, the facilities of the hospital and the medical treatment itself Even party politics sometimes have a bearing on the final result Furthermore the cooperation and the psychological attitude of the patient are of decisive importance In judging an unfavorable result of treatment it is imperative that we first evaluate all the environmental condition to which a physician is subjected Improvements in final results can only be accomplished if changes and improvements of these conditions are made

The distinction between unavoidable unfavorable consequences of an injury and avoidable unfavorable consequences due to treatment must be the guide in the search for improvement in the future

Examples of avoidable unfavorable results of treatment

Example 1 A woman aged 50, fell upon her right hand in the late afternoon Because of pain and swelling she went to the out patient department of the nearest large surgical hospital There she was examined by a doctor who ordered moist fomentations and was told to report again on the following morning Because of pronounced tenderness of the wrist joint she was sent to the X ray department for appropriate examination On the third day a sketch of an X ray was sent from this department with a note which stated that a fine transverse fissure could be seen on the ulnar side of the lower end of the radius On the original X ray film which we saw later, this fissure could not be seen Probably a minor defect in the film had been mistaken for it Thereupon a nurse supplied the woman with a padded wooden palmar splint extending from the fingertips to the elbow and a sling She was to report again after five and after ten days The splint was taken off both times for massage and movements of the wrist but the fingers and shoulder were not moved The splint was re applied and two weeks later was removed for good The fingers were now stiff She was discharged to her panel doctor He sent her to a higher panel doctor, who ordered massage and hot air treatment at a physiotherapeutic institute In this institute she was seen every week by a doctor Three weeks later massage was discontinued and diathermy ordered instead because the swelling of the fingers and back of the hand became worse Later treatment again was alternated between hot air and massage In the ninth week because of pain the shoulder was irradiated with ultraviolet light Altogether she was treated 62 times with hot air 14 times with diathermy 18 times with ultraviolet light and 24 times with massage In order to get to the institute she had to walk fifteen minutes to the streetcar stop and then travel half an hour by streetcar She was obliged to endure the cold for one and one half hours in order to enjoy 15 minutes treatment with hot air

After 15 weeks she was sent by the insurance company to have further treatment The fingers were stiff in a position of extension the fingertips atrophic, the fingerjoints thickened the back of the hand slightly swollen the wrist movable 20° in either direction from the mid position the elbow was almost free At the shoulder only 60° of abduction was possible and the hand could not be placed behind the back nor behind the head The shoulder was very tender to pressure The arm was always carried in a sling X rays showed no injury All the bones of the hand showed marked decalcification

The patient has up to now drawn 4200 S sick pay The cost of treatment is not known Some months will elapse before the fingers and shoulder become more mobile In the meantime she will receive high compensation She has lost her job and under present conditions will get no work

If a palmar splint extending from the fingertips to the elbow is applied to any person over 40 years old, even though he has had no injury, after two weeks the fingers will be stiff, and if the arm is carried in a sling all the time, the shoulder will become stiff too In a young patient this will never happen If in the presence of a small fissure a few millimeters long at the lower end of the radius no treatment is given, the pain disappears in two to three weeks and the hand is restored to full use after four weeks If an unpadded dorsal plaster splint is applied extending from the knuckles to the elbow (see Vol I/p 798), the pain disappears at once and the hand can immediately be used for all household duties provided it is kept dry If in addition the patient is shown how to open, close and spread her fingers, turn the forearm inwards and outwards, flex and extend the elbow, raise the arm vertically at the shoulder, lay the hand on the opposite shoulder, behind the head and behind the back, then no damage will be suffered by these joints at any age After the removal of the plaster splint the wrist which has been held firm becomes freely movable in a few days, and a woman with an injury like that described

above will be capable of the hardest work in four weeks at the longest At first these exercises should be supervised daily They occupy 20 to 30 seconds

Not only in the case of trivial fissures, but in all serious fractures of the lower end of the radius, full functional activity is attained after exact reposition by maintaining the fracture continuously immobile until the fragments have united — *that is, for three to five weeks* — and by requiring the exercises mentioned above The shoulder and elbow from the first day, and the fingers after three or four days, will have a full range of active movements and there will never be lasting damage

The question arises, *who is responsible* for the fact that this 50 year old but healthy woman after four months of tedious and apparently most careful treatment, has a useless arm and is thrown out of employment Is it the surgeon whose name is on the out-patient card of the institution where the volar splint was applied for 14 days? He has never seen her Is it the radiologist who gave an incorrect opinion based on a trivial defect in the film but who never had seen the patient? Is it the doctor who happened to be on duty in the out-patient department and who ordered the application of the volar splint? Or is it the nurse who applied the splint as ordered? The panel doctors who refered her to the physiotherapeutic institute certainly bear no responsibility What about the director of the institute, who saw the patient every eight days and in the tenth week declared that the shoulder had become stiff and tender?

The blame for the bad result lies in the system, which so organized the treatment of this simple case that five doctors who had no connection with one another had to share in the treatment

For comparison I would like to mention that none of our 172 industrial accident cases of Colles fracture of the years 1926—1930 draws disability compensation The average duration of treatment was 40 5 days

Example 2 A 44 year old painter fell and sustained a fracture of the right collar bone The same day a Desault bandage was applied which he wore for four weeks By the time it was removed eczema of the elbow and axilla had developed the elbow could be moved from 70° to 140° the arm could only be abducted 50° the hand could not be placed behind the head nor behind the back wrist and finger movements were free Roentgenograms showed abundant callus formation with considerable displacement of the fragments The patient was sent to a physiotherapy institute where he was treated with hot air and massage daily for five weeks As movement in the shoulder did not improve in the sixth week he was sent to another institution where he received daily mud baths for three weeks Thence he was sent to a neurologist because the pain was not better and the movements had not improved This physician demonstrated atrophy of the shoulder muscles and a zone of hypoesthesia and hyperesthesia Diathermy was given for four weeks because of these findings At the same time the electrolyte balance was investigated The treatment was then interrupted and the patient came to the insurance company for disability evaluation This was fixed at 30/ because the arm was atrophic and could not be raised above the horizontal position

After 4 months treatment the man could not resume his employment because as a painter he required full movement of the shoulder At present (1954) 100% compensation amounts to S 1200 at monthly earnings of S 1800 As his disability has been estimated at 30% of the full compensation, he receives S 360 per month *He used to earn S 1800* He has a wife and 4 children

Would it not have been better to have concerned one's self with the movements of the shoulder rather than with the eletrolyte balance? A whole series of physicians had shared in the treatment of this case One surgeon who had applied the first bandage, one radiologist, two physiotherapists, one neurologist, and different rating physicians — in spite of all this the result is poor

If a Desault bandage is applied to any person over 40 years old, even without an injury, the shoulder will have its mobility impaired for a long time In young patients this will never occur

If no bandage is applied for fracture of the clavicle, and if the patient is only shown how he should actively move all the joints of the arm from the fingers to the shoulder through their full range of movements from the first week on, stiffness of a joint will never occur, and the bones will be united after three to five weeks with more or less displacement Two to three weeks later the patient will be able to resume full employment If the fracture is reduced and placed on the splint shown in Vol I/p 519 and left for three to five weeks, and if all the joints of the arm are exercised actively during that time, not only will free movement be obtained, but usually also good position of the fragments and the patient will be fit for full work four to seven weeks after the injury

Schuppler followed up our cases of fractures of the clavicle, 65 of the 224 were industrial accident cases None received disability compensation The average duration of treatment was 44 5 days All had freely mobile joints and normal strength (Vol I/p 539)

Example 3 A 40 year old man was involved in an auto accident and was immediately taken to a hospital The surgeon found swelling and tenderness in the region of the elbow and the upper third of the forearm The patient was sent with a written note to the X ray department where a picture of the elbow and upper part of the forearm was taken by a technician The radiologist without ever having seen the patient reported the following findings the next day bending fracture of the ulna in the proximal half with small ulnar bending wedge distal fragment of the ulna displaced half the shaft's breadth towards the ulnar side No injury can be seen in the elbow region (figs 3042 3043) As the injury seemed from the X ray findings to be a comparatively unimportant fracture the surgeon applied the ill reputed Schede splint and sent the patient home (fig 3044 and see Vol I/fig 1163)

When he came to us a week later the elbow was much swollen and congested and could only be bent to a right angle On the radial flexor side a hard bony protrusion could be felt in spite of a swelling After removing the Schede splint it was apparent that the radial nerve was paralyzed Fresh roentgenograms of the joint taken exactly A P and exactly laterally showed that the head of the radius was completely dislocated forward (figs 1050 1051) Complete radial paralysis had been caused by pressure of the dislocated radial head

Under brachial plexus anesthesia with correspondingly strong traction and pressure the dislocated radial head was reduced It was retained by an unpadded plaster cast extending from the knuckles to the shoulder After eight weeks the radial paralysis had disappeared and the reduced joint and the fracture were healed After 12 weeks the movements were almost normal

If the dislocation had not been discovered in time, the head of the radius would have continued to press on the nerve and the paralysis would probably have been permanent Furthermore, the mobility of the elbow and forearm would have remained considerably restricted and the use of the right arm would have been limited to a great degree

Who ought to bear the blame for crippling this man, the surgeon or the radiologist? The surgeon had relied entirely on the radiologist and the latter had given an incorrect diagnosis based on an unsatisfactory picture taken by a technician, with the injured elbow poorly positioned Closer inspection even of this poor roentgenogram (the dorso-volar view) reveals that the shadow of the radial head overlaps that of the capitulum humeri If a marked swelling and congestion of the elbow is observed, the roentgenogram should always



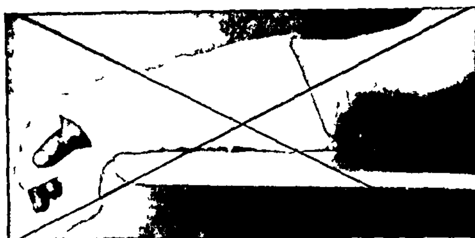
3042 3043

FIGS 3042 3043—Fracture of the ulna with forward dislocation of the head of the radius In the dorso volar picture the dislocation can only be recognized from the fact that the shadow of the head of the radius overlaps the capitellum of the humerus Compare with figs 3045 3046 In the lateral roentgenogram the dislocation cannot be seen because the humerus is rotated

be examined with the utmost care Besides the experienced surgeon realize that a fracture of the ulna with angulation and shortening is usually associated with a dislocation of the radial head If permanent disability follows such a fracture dislocation because it was not recognized and therefore inadequately treated, the cause for the failure lies in the organization that allows the roentgenologic interpretation and the treatment to be carried out by a doctor who has not had the necessary training in these fields *Inadequate instruction and organization!*

Example 4 A 22 year old student slipped and fell during an athletic event and sustained a fracture of both malleoli He went to a doctor who sent him to an X ray institute There a roentgenogram was made and reported on by the radiologis som hours later without his having seen the patient He declared that there was a fracture of both malleoli

with slight displacement The fracture was reduced under anesthesia and treated by a plaster cast To prevent stiffness the plaster cast was removed after four weeks Then electro therapy and massage were assiduously applied for eight weeks The ankle was always swollen and painful and walking only posible with a cane After three months the patient was



3044

Fig 3044—Fracture of the ulna and dislocation of the radius treated with a Schede splint Marked hematoma of the elbow Compare with figs 3042 3043 and 3045 3046



3045 3046

Figs 3045 3046 -Fracture of the ulna with forward dislocation of the radius This can easily be seen in the lateral roentgenogram because a true lateral has been obtained Compare with figs 3042 3043

sent to a spa for four weeks He continued to have pain after his return For an additional six months he had massage hot air diathermy or treatment with a pendulum machine alternately every other day Two years later the mobility was still much restricted The foot was turned outwards and remained in pes valgus position The patient walked with a slight limp and walking became painful after half an hour A roentgenogram showed that the talus was displaced outwards 5 mm and lay obliquely and that the malleoli had united in an

incorrect position The joint space was markedly narrowed and showed arthrotic changes According to the roentgenogram taken just after the accident the talus was displaced 2 mm outwards and after reduction it was in good position

In this case, too, the treatment was very intensive and of long duration, but the result was unfavorable in spite of the youth of the patient

If a fracture of both malleoli with lateral displacement of the foot is reduced accurately and fixed in a plaster cast for 8 to 16 weeks, depending on the degree of displacement, and if the patient is urged to walk during this time, the fracture-dislocation will unite in good position After removal of the plaster cast the ankle will at once have two-thirds of its normal mobility, a few weeks later, without any after-treatment, it will have complete range of movement and the patient will be able to walk normally

Here we have a young athlete severely and permanently crippled because of the three requirements for the treatment of fractures reduction, fixation until bony union has occurred, and exercise — the second had not been fulfilled Reducing a fracture dislocation is purposeless if, after the reduction, the fragments are not continually held in position until bony union has resulted Without a firm cast, or as a result of its premature removal, fresh displacement occurs in the joint, union takes place in malposition After-treatment is then useless, be it ever so prolonged and expensive Union in good position makes such after-treatment superfluous

What is the reason for the unsatisfactory result? The use of unsuitable methods of treatment as a result of inadequate training

(Similar clinical histories of malleolar fractures are given in Vol I/pp 48 and 49)

Example 5 A strong healthy 23 year old man suffered a fracture of the right femur on February 16 and was taken at once to a hospital The leg was shortened about 3 cm rotated outwards and considerably swollen Roentgenograms (figs 3047 3048) showed a *transverse fracture of he left femur at the junction of the middle and lower thirds* with displacement of the lower fragment backwards and inwards for the full width of the shaft and with valgus position of about 10° and recurvation of about 10° The records that accompanied the patient state A Kirschner wire was placed in the tibial tubercle under general anesthesia The limb was placed on a lower leg splint and traction applied from an overhead frame according to the plan of Bohler (so the progress notes state) Traction of 10 Kg On March 10 adhesive tape traction with pull on the thigh lower leg and foot of 5 Kg 5 Kg and 1 Kg respectively

On March 16 the first X ray control pictures were taken (figs 3049 3050) Displacement of the fragments had not been entirely corrected Traction through the tibial tubercle repeated but with 14 Kg for three weeks Then again adhesive plaster traction with little weight *(amount not specified)* In this arrangement angulation of the femur occurred with vertex of the angle pointing outward See control roentgenogram of May 6 (fig 3057) Operation advised May 27 open reposition Lane plate fixation Plaster cast from the pelvis to the sole of the foot with a window at the site of the incision Wound healed per primam The plaster cast was removed after six weeks Fracture not yet sufficiently solid Further rest in bed necessary Now daily massage and passive movements by an attendant

On July 15 attempt to mobilize the very stiff knee under anesthesia The patella was broken transversely without separation of the fragments Compression bandage immobilization with Cramer s splint

Repeat roentgen examination on July 21 (fig 3052) showed loosening of the screws and bending of the femoral shaft Fracture not yet consolidated The leg was still incapable of weight bearing A second operation was advised On July 22 a massive tibial graft was

fixed across the site of fracture by means of encircling wires Plaster cas from pelvis to the sole of the foot for six weeks After removal of the plaster cast (wound had healed per primam) renewal of massage and exercises and hot air treatments at firs in bed then from September 20 on in the Medico Mechanical Institute The fracture was now firm good callus leg could bear weight knee joint very stiff Walked at first with two crutches On Oct 22 went for out patient treatment on two canes (hot air massage pendulum machine)

From Dec 22 till Jan 4 in patient treatment at the hospital for mobilization of the knee joint which had been but little influenced by he medico mechanical treatment It was stiff in extension Under anesthesia it was flexed over a wooden block Suddenly an audible snap angulation took place at the site of the left tibia from which the tibial graft had been taken in July A walking plaster cast was applied at once A roentgenogram showed a fracture with angulation of the tibia Several days rest in bed On January 4 patient was discharged in walking cast for further out patient treatment Result of mobilization was negligible On January 20 the walking cast was renewed and the knee treated with hot air massage and exercises On February 10 the cast was removed the tibial fracture was firm

On March 30 the patient could walk with a cane the knee joint showing movement from 180° to 160°

The treatment of such a fracture of the femur in a strong healthy young man is fairly simple If a pin or wire is applied under local anesthesia through the tibial tubercle, the leg placed on a Braun splint, and if traction is applied with a weight equal to one-seventh of the patient's weight, the shortening and angulation usually disappear If roentgen observations are made the next day and every two or three weeks thereafter, the position of the fracture can be controlled and if necessary improved In eight to 12 weeks the fracture usually is firm in good position and the leg capable of bearing weight For the first few days the patient will be able to walk with the help of two hand walking-supports, and after eight to 14 days he can walk without a cane Without any after treatment the knee joint of a 23 year old patient should be freely movable 2 to 3 months later In about 1200 closed fractures of the femur which I have treated, the knee joint has usually had a range of movement of over 90° and was often normal (Vol I/figs 238—240, 277—280, Vol II/2159—2164, 2166—2022, 2042—2044, 2065, 2166 m—o)

In this case roentgenograms, after four weeks (figs 3049, 3050), showed that shortening had been corrected, but that the lower fragment was displaced backward by the full width of the shaft and that an angle (open anteriorly) of 10° was present The functional capacity after fractures of the femur remains unimpared even if the fragments remain displaced by the full width of the shaft, provided that shortening and angulation have been corrected (Vol I/figs 261—267, 271—276, Vol II/figs 2016—2022) The anteriorly open angle could easily have been corrected by placing a pad under the site of fracture, or by pulling the knee distally over the bend on the Braun splint as shown in Vol II/figs 2007, 2008 Instead of this in the fifth week traction of 14 Kg was applied for three weeks The effect was not checked by roentgenograms Usually such strong traction damages the knee joint and makes it loose In addition the callus formation is delayed After seven weeks adhesive tape traction was applied, but with too little weight The result was marked outward angulation of the femur at an angle of 30° Such angulation can easily be recognized even without roentgenograms When a roentgenogram was taken after 11 weeks, it showed the marked angulation of 30° and good

callus formation (fig 3051) Such angulations can easily be corrected under short anesthesia and good position retained by traction of 10 kg or by a plaster cast In five or six weeks the bone would have been firm and fit for weight-bearing, and some weeks later the knee would have been freely mobile Instead of this the fracture was operated upon, the good callus removed and a Lane plate applied followed by plaster immobilization for six weeks Although at the end of this time the fracture was not yet sufficiently firm, a fresh cast was not applied Instead daily massage and passive movements were administered without improvement After such operations, in which an incision through the vastus lateralis is made close to the knee joint,



3047 February 16 3048 3049 March 16 3050

Figs 3047 3048 —Fracture of the femur at the junction of the middle and lower thirds Medial and posterior displacement by the full width of the shaft 3 cm shortening with 10° valgus position and 10° recurvation

Figs 3049 3050 —Roentgen check to figs 3047 3048 after 33 days The shortening has been corrected The distal fragment is still displaced medially by half the width of the shaft There remains only a suggestion of valgus position Recurvation is unchanged Good callus formation *especially in the anteroposterior view The lateral view shows that the femur has not been* pulled far enough onto the Braun splint (compare with figs 2007 2008)

usually lasting damage to the mobility of the knee results, especially after previous distraction In order to improve this limitation of motion the knee was bent with such force that the patella broke and the fracture site of the femur became loose, even though it had been fixed with screws It again showed angulation of about 20° (fig 3052)

Even then, if the femur had been straighened under short anesthesia and a plaster cast again applied, the patient would have been able to walk in one or two days and in a few weeks the fracture would have been firm Instead of this another still more formidable operation was undertaken A long heavy tibial graft was implanted into the site of fracture and a plaster cast again applied for six weeks Once more massage and passive movements were given By this time the fracture was alleged to be firm and able to bear weight, but the knee was stiff A roentgenogram on December 19 showed however, that the fracture was not yet firm, otherwise it would not have assumed a varus

position of 15° This also was due to the fact that the lower end of the graft had not been fixed by a wire loop (fig 3054) As the mobility of the knee had not improved in spite of medico mechanical treatment the knee joint was again manipulated under anesthesia five months after the second operation and with such force that the tibia broke at the donor site of the graft

A stiff knee can never be mobilized by forceful manipulation which only produces further serious damage In such cases mobility can only be restored by the operation according to Payr (see Vol II/pp 1473—1476)

The result in this case after thirteen months' intensive treatment is a crooked femur and a stiff knee joint in a healthy young man of 24



3051 May 6 3052 July 21 3053 July 22 3054 December 19

Fig 3051 Same case roentgen check after 80 days Varus position of 30° good callus formation

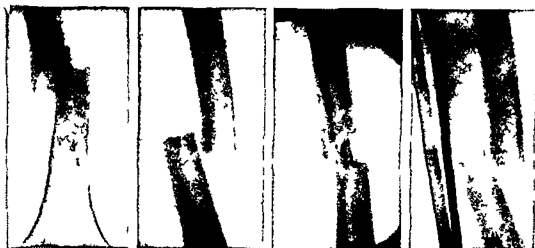
Fig 3052 —Same case Roentgen check after 156 days after 75 days open reduction using a Lane plate Varus of 20° good callus at the medial side The vigorous callus that was visible in fig 3051 on the lateral side has apparently been removed at operation and has not reformed

Fig 3053 —Control film of same case immediately after bone graft Good alignment

Fig 3054 —Same case Roentgen check after 308 days 151 days after the bone graft. Bony union in 15° varus

The most important points in the treatment of every fracture are reduction, uninterrupted immobilization until the fracture has healed, and exercises of as many joints as possible during the period of immobilization In fractures of the femur the fragments are best maintained in position by intramedullary nailing or by continuous traction But this should not be done with too little or too much weight, but only with the correct weight in the right direction Further the traction should not be discontinued before the fracture is firm After an operation with Lane plates or with a bone-graft, a cast should be applied until the callus is firm and able to bear weight This may take six weeks or longer, as in this case The cast must be kept on for a longer time because neither the Lane plate nor the tibial bone graft can by themselves hold the fragments together Attempts to move stiff joints should never be made with great force Only by using small forces which act for

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3047 February 16 3048 3049 March 16 3050

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usually lasting damage to the mobility of the knee results, especially after previous distraction In order to improve this limitation of motion the knee was bent with such force that the patella broke and the fracture site of the femur became loose, even though it had been fixed with screws It again showed angulation of about 20° (fig 3052)

Even then, if the femur had been straighened under short anesthesia and a plaster cast again applied, the patient would have been able to walk in one or two days and in a few weeks the fracture would have been firm Instead of this another still more formidable operation was undertaken A long heavy tibial graft was implanted into the site of fracture and a plaster cast again applied for six weeks Once more massage and passive movements were given By this time the *fracture* was alleged to be firm and able to bear weight, but the knee was stiff A roentgenogram on December 19 showed, however, that the fracture was not yet firm, otherwise it would not have assumed a varus

never with the development of a spreading cellulitis Of more than 5000 fresh open fractures of the fingers with injuries to tendons and tendon sheaths that were treated in the accident hospital form 1926—1939, 96% healed without disturbance and without a drop of pus A spreading cellulitis resulting in death of the patient occured only once (vacation case see Vol I/p 1061)

This previously healthy man was treated with remarkable thoroughness after a comparatively slight wound Whether or not this intensive treatment was suitable is another question Practically everything recommended in the latest literature was employed with the exception of X ray radiation and blood transfusions, only the immobilization was completely forgotten

The first major mistake was made in not excising the wound, the second, the use of situation stitches instead of allowing the unexcised wound to remain open, the third, the immediate use of moist dressings Even in carefully excised wounds infection generally occurs if the skin is not kept dry Because of the lack of immobilization and because of the daily soaks with change of dressing, infection spread into the forearm on the sixth day But even then the manipulations were continued, until the suppuration had not only involved the whole hand and forearm but had spread into the body and the blood stream

In the course of 23 days the patient was anesthetized six times In the last days 8 to 10 injections of different medicaments were made into the bloodstream, muscles or under the skin daily, in addition to the oral administration of other remedies When septic bloody stools appeared, antihemorrhage drugs were given How long could any person, even without septicemia, be expected to survive the administration of so many ' remedies?

Example 7 A 34 year old machine worker on lifting a roll of paper weighing 25 Kg felt a stabbing pain above his right hip This was work he was accustomed to Next day he went to the hospital There tenderness *below* the *right* iliac crest near the sacroiliac joint was found He was treated with hot air and fomentations for some weeks In later examinations tenderness was always present at the same location After som weeks he was dismissed from the hospital as fit to return to work He had been previously hospitalized several times for a similar complaint in former years Some months later a roentgenogram of the sacroiliac region was made at another institution which showed no abnormal changes in the bones or joints A year later the patient was seen at a medical department There arthritis of the sacroiliac joint was diagno ed Two years after the accident he went to another hospital where the X ray report showed a supposed ununited fracture of the *left* transverse process of the first lumbar vertebra After this diagnosis an orthopedic corset was ordered He was supposed to have been told that his spine was broken and that he had had the pain because the fracture had not been recognized and because he had been wrongly treated from the outset

Thereupon he sued for damages and compensation from the doctor who had first treated him for the omission of an X ray examination and incorrect treatment requesting a total of 300 000 S ($ 11 540 or DM 50 000) During the law suit which in the course of two years went through all three courts the fact was established that the patient had no fracture of the left transverse process of the first lumbar vertebra but merely a congenital first lumbar rib (see Vol I fig 608) This lumbar rib was 30 cm distant from any point where he had originally had the pain and furthermore it was on the opposite side of the body The accused doctor was cleared of negligence by all three courts but it cost him 10 488 S ($ 403 00 or DM 1748) (lawyer s fees e c) to establish his innocence The complainant could lose nothing because he was on relief and his case was prosecuted by the public attorney

It is interesting that in spite of the judgment he continued to wear the corsets which had been provided for him by three different charitable organizations and on account of his alleged fracture of the spine he continued to draw 50 per cent disability compensation

a long time can they again be restored to mobility, or in the case of a knee *joint by an operation* (quadriceps plasty according to Payr)

If the surgeon had been aware of these, the simplest rules in the treatment of fractures, four major operations upon the fracture would not have been necessary By each of these the patient was more damaged *His present condition is not the unavoidable result of the accident, but it is the outcome of treatment which was unnecessarily active, energetic and also inconsequent because the surgeon lacked adequate training* (For other similar histories of fractured femurs see Vol II/p 1447 and Vol I/figs 258—260 Vol II/figs 2091 to 2098)

Example 6 A 36 year old previously always healthy man got his right hand into a circular saw All five fingers were injured on he flexor side On the second and fifth fingers the flexor tendons were acerated but not cut through In the fifth finger the proximal *phalanx was severed and in he thumb the distal joint was opened He* immediately went to a hospital where under general ane thesia some stitches were inserted *without excising the wound* Over this a moist dressing and a splint were applied Dressings were changed daily

On the sixth day the fifth finger was blue and cold

On the seventh day this finger was removed at the metacarpophalangeal joint under ether anesthesia Further moist dressings were applied

On the ninth day the temperature rose to 39 5 C The forearm was tender

On the tenth day the forearm was incised and drained under general anesthesia Evacuation of considerable pus

On the twelfth day the patient was given Omnadin and Domopon Temperature 38 6 C Because the suppuration was spreading the ligamentum carpi transversum was divided and the tendon sheaths in the palm opened Fresh ncisions were made into the forearm Drainage by rubber tubes and gauze

On the fourteenth day the temperature had fallen Omnadin was given intravenously *The hand and forearm were soaked daily*

From the fifteenth day on the wounds were treated with Besredka antivirus daily after the soaks

On the sixteenth day the temperature was again very high Fresh incisions were made in the forearm under ether anesthesia

On the seventeenth day Hexeton was given three times with other cardiac drugs as well as electrocollargol and 100 cc of streptococcal serum

On the eighteenth day Hexeton Omnadin caffeine and 100 cc streptococcal serum were given

On the nineteenth and twentieth days besides the daily baths and Besredka antivirus solution electrocollargol was injected and cardiac drugs were administered t i d as well as Omnadin and Domopon

On the twenty first day the back of the hand showed fluctuation Under ether anesthesia some incisions were made and dra ned Otherwise treatment was continued as on previous days

On the twenty second day there was blood in the stools Intravenous injections of Afenil and stryphon were given as well as styptica three times a day by mouth together with calcium stryphon and Afenil The remedies of previous days were repeated as the report shows

On the twenty third days again blood in the stools Styptica were given three times by mouth calcium subcutaneously and clauden intramusculary In the evening the patient died.

If in such *an injury the wound is exactly excised under* local or brachial plexus block anesthesia, if the skin and the skin only is sutured and if the hand is, after insertion of a drain for 24 hours immobilized by a dorsal plaster splint and the fingers with volar finger splints the wounds left exposed without dressing, the *whole arm raised on an abduction splint* (see Vol I/pp 954—1072) healing usually takes place without sign of inflammation, or with only the development of small localized stitch abscesses but

fact that methods of treatment and types of organization exist with which the above pictured treatment damages can be avoided The time will certainly come when one will care for accident victims in the same manner as one cares for the victims of infectious diseases, as they represent a national health problem of the first rank

Malpractice [1, 2] I was once called as expert witness in a malpractice suit regarding a crookedly healed femoral fracture It was a type of case of which there are hundreds I explained that one would have to investigate where the accused surgeon had learned the treatment he had used If he could prove that he had learned it from his professor of surgery, one would have to hold his professor responsible If his professor in turn had taught an unsatisfactory method, one would have to hold the minister of education who appointed the professor responsible Since, however, the minister of education as a rule cannot understand anything about fractures of the femur, the man that had appointed him must be responsible In this case it was Kaiser Franz Josef I Thereupon the defendant was acquitted

That one can avoid most of the damage resulting from treatment with proper organization and use of proper methods of treatment is proved by the fact that, to my knowledge, no damage of the sort shown in figures 3055 to 3066, occurred among the 90,000 hospitalized and 600,000 ambulatory patients that have been treated in the Accident Hospital in Vienna in the 31 years from 1926—1956, if they came to us immediately after their injury and did not discontinue treatment before they were discharged If, for example, a patient is not sent to us until two days after an injury with ischemia because of constricting bandages, contracture or gangrene cannot be avoided Unfortunately we too have had bad results following treatment, as does everyone else

Figures 3094—3096 show that, even in 1917, 40 years ago, we were successful in often achieving a high degree of motion and in avoiding shortening or malalignment not only in closed fractures of the femur but even in infected gunshot fractures

II THE ECONOMIC SIGNIFICANCE OF ACCIDENT SURGERY

Number and Severity of Accidents

The number and severity of accidents is increasing exceedingly rapidly in all parts of the world

According to the statistics of Demel [3] the following number of injuries were treated as in-patients and out-patients in the accident unit of the First Surgical Clinic of the university in Vienna until the year 1925

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[1] Bohler L Aussprache zu Hellner Erfahrungen an sogenannten Kunstfehlergutachten Heft Unfallheilk 43 149—150 1952

[2] Bohler L Aussprache zu Muller u Kostlin Ärztliche Haftpflicht Hefte Unfallheilk 45 100—101 1953

[3] Demel Hoche und Moritsch Die Unfallstation der I chirurgischen Klinik der Universitat Wien Wien Verlag Springer 1925

Two years later he applied for an increase of this sum Thereupon the compensation was *entirely cancelled, and this was later confirmed in court* after an examination by yet another physician The man then threatened to shoo the doctor who first treated him and was therefore taken into custody for observation He later shot himself

Because of an error in interpretation of the roentgenogram this man had been given a supporting corset *He was made into a compensation neurotic* Even if the diagnosis of a fractured transverse process had been correct, he would not have required a corset, because such a fracture does not impair the weight-bearing capacity of the spine

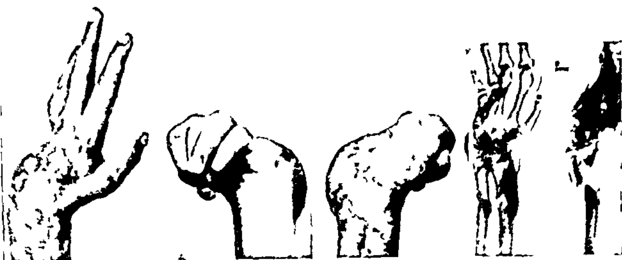
Another example will show how an injured man may be influenced one way or another by what he is told

Example 8 A chauffeur was caught between a truck and a wall He suffered severe injuries and was admitted to hospital with many broken ribs subcutaneous emphysema and hemothorax *The severe general symptoms disappeared after a few days and after three* months he returned again to his work Six months later he had pain in his back and was seen by his panel doctor and roentgenograms were made As the result of this examination he was informed that his fourth dorsal vertebra was broken and that he would never be able to work again Thereupon this man who had worked for three months collapsed physically and mentally and came to our hospital the next day to report to us He had previously been very satisfied with our treatment but now it was evident from his story that he felt we had overlooked his broken back We made a roentgenogram and found that the spine showed no sign of fracture So we then obtained the roentgenogram from the panel doctor This too showed no abnormality The shadows of the ribs scapula and humerus were superimposed over the fourth dorsal vertebra so that the appearance had been mistaken for a fracture When the man next day was informed that according to all the roentgenograms the backbone was not broken he raised himselt up again from his stooped posture furthermore when it was pointed out to him that he could not have undertaken hard work for three months with a broken back he realized it with joy and being psychologically cured returned at once to his work

While on the one hand there are many people who on account of alleged injury to the spine wear spinal braces for years and draw high compensation, on the other hand there are many with severe injuries of the spine which have been overlooked Blame may be placed on the omission of X-ray examination, on the omission of a lateral roentgenogram, on technically faulty roentgenograms which are not diagnostic, or on a lack of knowledge of those who ought to *interpret the films*

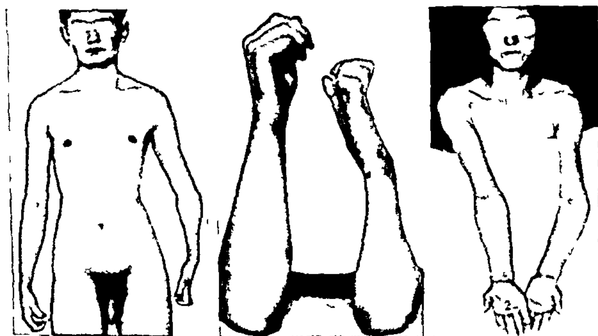
Figures 3055—3066 represent only a small selection of hundreds of similar pictures of patients in my collection and of thousands that I have seen without photographing them In fact the number of the other *avoidable complications* listed on page *2162* which *do not lend themselves to such striking illustration* as those shown above, is much greater

Many who have seen these pictures have said that the physicians who treated these cases should be sued for malpractice However this would not make these patients well *The remedy can only be found in improved training and better organization* in the field of traumatic surgery Others felt that such bad results could no longer occur in this day and age However, we almost daily see one or more patients with more or less damage resulting from treatment Analysis of the medical records again and again shows *the same* cause, namely, inadequate training and inadequate organization with lack of suitable, properly oriented personnel and sufficient equipment, in spite of the



3057 September 21 1949

Fig 3057 — Malposition of the left hand 15 months after an open fracture of the forearm Because of inadequate wound excision an infection developed and because of too short a period of immobilization a flexion contracture of the wrist joint developed with hyperextension of the fingers and inability to close the fist *By better training of doctors and continued refresher training such damages can be avoided*



3058 June 4 1950 3059 March 2 1953

Fig 3058 — Growth disturbance of the left arm with flexion contracture at the wrist joint as well as in the middle and end joints of the fingers with associated hyperextension in the metacarpophalangeal joints after a supracondylar fracture of the humerus which had been inadequately reduced and immobilized for too short a period of time The cause was a constricting bandage *By better training of doctors and continued refresher training such damages can be avoided*

Fig 3059 — Angulation at the elbow following a supracondylar fracture of the humerus that was inadequately reduced and immobilized for too short a period of time The cause of the angulation is the same as that in fig 3058



3055, January 8, 1948

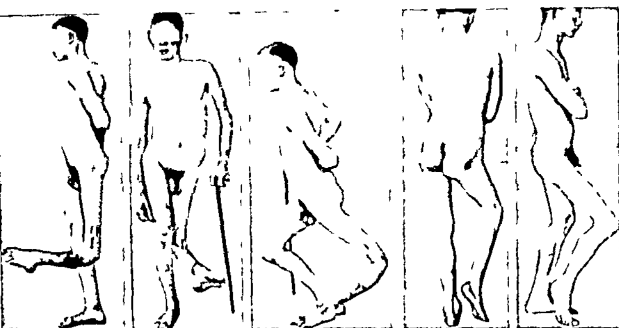
Fig 3055—Crippled hand of a 20 year old worker who sustained a puncture wound of the thumb Because the wound was not cleansed and immobilized in time a tendon sheath infection of the thumb and little finger developed as in example 6 on page 2172 Since the introduction of antibiotics such progressive tendon sheath infections have become rare Many finger tendons have sloughed This is a result of treatment which can usually but not always be avoided The flexion at the wrist and the hyperextension of the fingers that render the hand completely useless represent an avoidable treatment complication that can always be avoided by a suitable plaster cast In this instance no improvement is now possible



3056 December 13 1949 3056 a

Fig 3056—Radial deviation of the hand to almos a right angle Produced in a 15 year old boy after an open fracture of the forearm with a small wound This was not excised and the fracture was neither reduced nor immobilized Moist compres es infection and sloughing of sequestra The hand then deviated radially The fingers can be completely extended and flexed only 50% Three months hospitalization then massage passive motion and radiant treatment for 8 months The cause of the unsatisfactory result with pseudarthrosis of the radius and angulation at the wrist is the omission of immobilization *By better training and continued refresh r training of doctors these damages can be avoided*

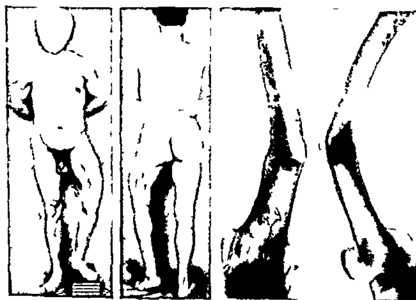
Fig 3056 a—Same case after operative correction of the pseudarthrosis and the malposition by shortening of the ulna freshening the ends of the pseudarthrosis of the radiu and arthrodesis of the wrist joint



3064 October 10 1947 3065 March 28, 1955

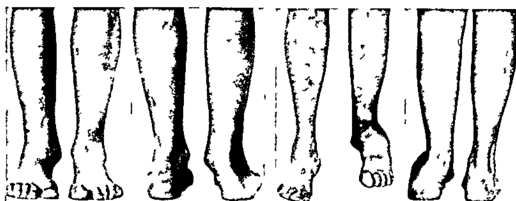
Fig 3064 —Eighteen year old boy who sustained a small drop wound of the left knee joint at the age of 6 years This was neither excised nor immobilized As a result infection of the knee joint with sepsis developed Hospitalized nine months Three years later arthrodesis Two years later increasing angulation The cause of the infection is the omission of wound excision and especially of immobilization because of inadequate training of the doctor and the cause of the marked angulation *inadequate organization* without keeping the patient under observation

Fig 3065 —Fifteen year old boy who sustained a puncture wound of the right knee at the age of 12 Ointment and dressings followed by knee joint infection Hospitalized seven months Ankylosis of the knee at 100° flexion The cause of this condition is *inadequate training* of the doctor and *inadequate organization*



3066 September 18, 1949

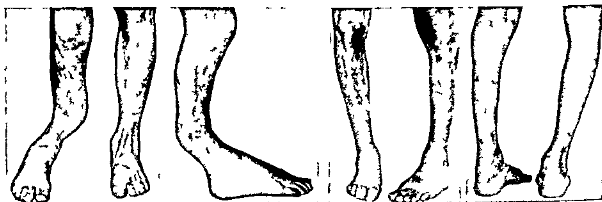
Fig 3066 —Angulation and rotation of the left femur with 8 cm shortening and mobility of the knee from 150°—125° after a *closed* fracture of the femur Treatment Traction after 3 months wire suture with infection Hospitalized 14 months The cause of the unsatisfactory result is the *inadequate training* of the doctor compare with example 5 on pages 2168—2171



3060 February 27 1951 3061 June 8 1954

FIG 3060—*Closed* fracture of both malleoli on the right ten months after injury Treatment Application of a plaster cast for four weeks then massage passive motion, irradiation injection of calcium etc *By better training of doctors and continued refresher training such damages can be avoided*

FIG 3061—*Closed* fracture of both malleoli on the left in a 38 year old woman two years after injury Treatment application of a padded plaster cast that produced pressure sor s and led to an infection of the joint Seven months hospitalization Fistulae closed after 13 months The cause of the malposition of the foot is the same as in fig 3060



3062 Aug 4 1954 3063 Nov 28 1955

FIG 3062—Marked angulation of the right lower leg three years after a *closed* fracture of the lower leg which was first treated in traction and then in plaster The cause of the angulation is *inadequate organization* because the patient was not kept under observation and the leg could therefore become bent to this degree Angulations of this degree are rare

FIG 3063—Minimal angulation and marked rotation of the left lower leg after a *closed* torsion fracture of the lower leg six months after the injury Treatment Traction with too much weight (7 Kg) for eight weeks Then 12 weeks lower leg walking cast The cause of the angulation and the rotation is the result of the use of too much weight for traction and the technically incorrectly applied cast because of *inadequate training* of the doctor Such malunions are common

Carstensen[1] has reported on the increase in accidents in general as well as of traffic accidents in all Germany and in Hamburg

Injured and killed in auto accidents in all Germany

	Injured in traffic accidents	Killed in traffic accidents
1950	150,688	6,328
1954	314,393	11,655

According to these figures the number of injured has increased 108% in 5 years and the number killed has increased 83%

In the city of Hamburg the following statistics are available for comparison for 3 years

	Licensed motor vehicles	Traffic accidents	Injured in traffic accidents	Killed in traffic accidents
1938		10,480	6,195	100
1950	59,000	13,359	5,817	171
1954	109,501	27,379	12,198	288

In the university surgical clinic in Hamburg the following types of injuries were treated

1950	2649	total number of injured, of these	1954	3839	total number of injured, of these
	478	traffic accidents		1088	traffic accidents
	569	industrial accidents		783	industrial accidents
	1602	sports and miscellaneous accidents		1968	sports and miscellaneous accidents

The number injured in traffic accidents had accordingly increased 127% and the number injured in industrial accidents has increased only 37% From this it is evident that the type of accident has basically changed Much more important is that the traffic accidents are as a rule considerably more severe than the others From this one can only conclude that their treatment requires a corresponding organization

Working Days Lost as a Result of Accident

The figures published on working days lost as result of sickness and accidents in 1956 in the Munchen med Wchschr[2] are also interesting

On the basis of investigations that were undertaken by the department of Medical Labor Research of the Institute for Applied Anthropology in Heidelberg and that are based on some 16 million workers in Germany the following *loss in working days occurs yearly*

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[1] Carstensen Unfallstatistik aus der chirurgischen Universitatsklinik Hamburg Eppendorf Monatsschr Unfallheilk *59* 65—70 1956

[2] Munchen med Wchschr *98* 1180 1956

1910	1,004
1924	6,100
1929	more than 10,000
1956	14,821

The accident unit of the Second Surgical Clinic of the University had approximately the same number because admissions were alternated every 24 hours between these two clinics

In the Accident Hospital which was opened in 1925 the number of patients increased much more rapidly

1926	3,839
1929	8,728
1956	45,417

In addition to these are the 26,316 patients treated in 1956 in the new Accident Hospital (Vienna XII)

The General Insurance Company in Vienna reported the following number of industrial accidents for all Austria

1938	40,657
1948	88,106
1951	129,002
1955	153,433

In the various national health service panels 25 to 35% of all reports of sickness or accident are for accidents

The increase of traffic accidents in Vienna alone and in all of Austria show the following numbers

1 For *Vienna alone*

	Licensed vehicles	Traffic accidents	Injured in traffic accidents	Killed in traffic accidents
1946	19,506	5 274	4,402	333
1949	55,231	10,467	6,276	318
1952	74,236	13,180	6 787	164
1955	130,331	24,019	11,165	160

2 For *all of Austria*

	Licensed vehicles	Traffic accidents	Injured in traffic accidents	Killed in traffic accidents
1952	349,338	28 077	23,169	777
1955	616,685	61 401	51,091	1,485

In Vienna the number killed has sharply decreased since 1946 because the members of the occupation forces drove more carefully in the later years

It can be seen from the statistics from all of Austria that currently the risk of life is greater driving outside Vienna than in Vienna

Insured persons	Reported industrial & non industrial accidents	Patients to whom or to whose survivors pensions were paid in 1954: Total number receiving pensions	No added in 1954: all together	totally disabled	killed	Survivors of those killed who first received pensions in 1954
1 763 000	IA 128,275 NIA 72 938 201,213	IA 44 512 NIA 11 896 56 408	5 594	?	IA 338 NIA 454 792	753

In addition to the sum of 201,213 reported injuries are 126,857 very minor injuries

Germany with 47,557,926 inhabitants According to the statistical and financial report of the Bundes Ministry of Labor concerning the state regulated accident insurance in 1954 there were in West Germany

in 36 industrial trade associations	14,542,058	
in the 18 agricultural trade associations	8,954,602	
in the community accidents insurance associations	4,757,072	
in minor government officials insurance	2,265,746	persons insured
Total	30,519,448	

Disability cases to whom a pension was paid for the first time in 1954, a compensation for sickness according to paragraph 559 d of the Reichs Insurance Regulation, a death settlement or a settlement according to paragraph 619 of the Reichs Insurance Regulation

Insured persons	Number receiving pensions from previous years	New cases added during the business year	Total	Sequelae of the injuries and diseases: 1 Death	2 Disability: A Total	B Part	Survivors of those killed to whom a disability pension was paid in the business year for the first time
30 519 479	717 082	133 036	850 118	7 976	1 260	123 800	11 898

Austria Payments of the General Accident Insurance Company in Vienna in the year 1955 in Austrian shilling [1]

[1] 100 Austrian shillings equal about 4 U S dollars or 16 marks (German) or about 16 francs (Swiss)

Accidents	some 40 million workdays
Upper respiratory infections	some 26 million workdays
Diseases of the rheumatic group	some 23 million workdays
Diseases of the circulatory system	some 22 million workdays
Stomach and bowel disorders	some 18 million workdays
Diseases of the "lymphatic system	some 11 million workdays
Furuncles and abscesses	some 8 million workdays
Other disorders of the locomotor system	some 6 million workdays
Diseases of the reproductive organs	some 6 million workdays
Pulmonary tuberculosis	some 5 million workdays
Diseases of the gallbladder and biliary system	some 4 million workdays
Diseases of the urinary system	some 4 million workdays
Diseases of the nervous system	some 4 million workdays
Cancer	some 1 million workdays

Accordingly the loss of working days from industrial accidents represents 22 5%

Economic Significance of Accident Insurance

This can be seen from the following figures

Austria with 6,918,969 inhabitants According to the report of the General Accident Insurance Company for Austria in Vienna, in the year 1955, 1,793,120 industrially employed and self-employed individuals were insured against accidents In addition there is an Agricultural and Forestry Accident Insurance Company with 1,624,034 insured individuals The railroads have 90,161 workers insured

The following table shows the number of accidents and occupational diseases and their consequences in the group covered by the General Accident Insurance Company

Insured persons	Industrial accidents & occupational diseases reported in 1955	Patients to whom or to whose survivors pensions were paid in 1955				Survivors of those killed who first received pensions in 1955
			No added in 1955			
		Total number still living & receiving pensions since 1889	all together	totally disabled	killed	
1 793 120	153 433	49 875	7 706	11	464	945

The oldest surviving individual receiving disability pension was born in 1861 and sustained his injury in 1889

Switzerland with *4,714,922 inhabitants According to the Report and* Computation of the Swiss Accident Insurance of Lucerne there were in 1954, 1,763,000 employed workers insured against industrial (IA) and non industrial accidents (NIA)

Femoral fractures	89.2% received an average of 42.17% disability,
Lower leg shaft fractures	80.7% received an average of 27.39% disability,
Ankle joint injuries	66.8% received an average of 14.25% disability,
Fractures of the humerus	78.1% received an average of 14.25% disability
Forearm fractures	62.0% received an average of 13.09% disability

While in Germany the accident insurance is divided according to trade associations, Austria has a territorial classification, i e, the industrial workers of the entire country are insured with the same organization, while agriculture and forestry and the railroads have their own Accident Insurances The Austrian statistics therefore provide an approximate cross section of the general results of treatment in the entire country The injured patients were formerly, that is, before 1911, treated by general practitioners and in larger and smaller hospitals and only seldom in the university hospitals, since these at the time (see pp 2196—2199) only exceptionally admitted accident victims

In the case of the German trade associations comparisons are much more difficult, since the various occupations embrace markedly variable human material The strongest men are united in the miners' trade associations for instance Most of these are less than 40 years old The greatest problems in treatment begin as a rule after the 40th year Among the brewers and maltsters on the other hand, individuals of the heavy pyknic type are employed in the main In these individuals for instance a mild sprain of the shoulder can lead to persistent complaints

Thiem,[1] one of the most experienced men in disability evaluation of prewar times, in 1914 published the results that he had found in the follow up examination of the members of the miners trade associations, the industrial trade associations and in agricultural workers

428	fractures of the femoral shafts	289 (67.5%)	received a permanent disability pension
50	fractures of the neck of the femur	48 (96%)	received a permanent disability pension,
2243	fractures of the lower leg	983 (40%)	received a permanent disability pension
369	fractures of both bones of the forearm	143 (39%)	received a permanent disability pension
622	Colles fractures	162 (26%)	received a permanent disability pension

Of 361 fractures of the femur, that could be evaluated, only 21 had healed without shortening, 220 had shortening of more than 2 cm, and 73 had shortening of more than 4 cm

The average results in Germany were then somewhat better than in Austria, even though they still left much to be desired

In the last few years better results have been achieved than formerly due to better methods of treatment and better organization This can be seen from the reports that have been published from the patient material of the Accident Hospitals in Bochum, Graz and Vienna All of our clavicle fractures, for instance, have healed without permanent disability, as well as all of the ordinary radius fractures including the open ones and the comminuted ones That unsatisfactory results of treatment occur, even now, can be seen from the six cases presented in the general section on pages 2163—2173 as well as in figures 3055—3066 and 3087 These cases were taken from a large number of similar observations

[1] Thiem Festschrift zur Eröffnung des neuen Krankenhauses in Cottbus 1914

Medical treatment pensions and settlements	Investigations and control expenses	Legal expenses	Accident prevention	Admin	Misc	Total
256 433 511	1 856 441	667,014	1 902,513	20 246 229	19 080 823	300 186 533

The total expenditure of the General Accident Insurance Company in Vienna in 1955 came to S 300,186,533

The total income of the General Accident Insurance Company in Vienna in 1955 came to S 333,573,238

Switzerland The total expenditure of the Swiss Accident Insurance Company in Lucerne in 1954 amounted to 1,041,412,184 Swiss francs

Sickness compensation medical treatment pensions & settlements	Legal expenses	Accident prevention	Administration	Capital	Total
IA 92 424 341	101 916	1 707 272	IA 11 226 779	IA 618 733 000	IA 724 643 265
NIA 48 691 724			NIA 5 843 441	NIA 261 008 000	NIA 316 768 919
141 116 065			17,110 220	879 741 000	1 041 412 184

The total income of the Swiss Accident Insurance Company in Lucerne *in 1954 came to 1,046,822,880 Swiss* francs

The large sums for income and expenditures in Switzerland is due to the fact that she still uses accumulated capital for expenditures

Germany All trade associations together as well as the community accident insurance associations and minor government officials insurance had the following total expenditures in D marks

For medical treatment pensions and settlements	For investigation of accidents and determination of disability rates	Legal	Accident Prevention	Admin	Misc	Total
874 036 778	18 106 636	817 382	20 088 021	77 696 281	9 193 674	1 002 938 772

The Ministry of the Interior in Vienna formerly issued a report every five years about the Workers Accident Insurance Companies of old Austria The last one appeared in 1917 and presented the figures for the years 1907—1911 This report shows that the Workers Accident Insurance Company for Vienna and Lower Austria paid permanent disability compensation

Consequently in 124 fractures of long bones that were treated in the Accident Hospital 370,977 shillings were saved in disability payments in 1929 as compared to 1911

The operational cost of the Accident Hospital was 396,000 shillings in 1929 This expense could be almost completely covered by the savings in the disability payments in these 124 fractures so that the other 6,000 injured patients were actually treated without cost The Austrian shilling was at that time worth 8 times as much in purchasing power as today One German mark at that time was worth 1 20 shillings, and 1 U S dollar, 5 shillings

In all discussions about accident surgery usually only fractures of the long bones are considered These formerly amounted to only 8 or 9% of the injured that received disability payments Numerically the most common are the hand and finger injuries Hand injuries amount to 7%, finger injuries to 37%, or both together to 44% of all accidents, receiving disability payments In 1911 hand injuries were on the average, that is calculated on the basis of all reported cases, paid 10% Finger injuries on the average 5 54%

Before 1934 disabilities of 8 to 20% were also compensated Since that time all payments under 20% were cancelled

According to the statutes in force concerning disability payments in 1932, the following amounts would have had to be paid for

32 fractures of the humerus	S 153,960
174 fractures of the forearm	S 543,283
37 fractures of the femur	S 364,320
166 fractures of the lower leg	S 1 071,571
217 ankle injuries	S 742,284
626 fractures of the long bones all together	S 2 875,418
589 hand injuries	S 1,345,151
2905 finger injuries	S 3,859 466
(these last three types of injuries together)	S 8 080 035

The disability payments for hand and finger injuries alone amounted to almost twice the amount for the long bones Therefore these merit particular attention

In hand and finger injuries severe disability was produced, particularly by wound infections These can usually be avoided by primary wound excision as described in Vol I/pp 1057, 1058

For completeness it should be added that for the following injuries remaining after the fractures of the humerus and forearm and hand and finger injuries have been subtracted

387 arm injuries	S 1 450 838
1657 leg injuries (after fractures are subtracted)	S 2 527 718
257 head injuries	S 593,308
345 eye injuries	S 1 435 200
255 trunk injuries	S 775 792
26 injuries of the vertebral column	S 115,192
408 multiple injuries	S 886,485
25 electrical injuries	S 25,560
3300 injuries were paid in disability payments	S 7 810 093

Wette,[1] in 1932 evaluated 46 dislocations of the shoulder, 137 Colles' fractures, and 120 malleolar fractures occurring in workers insured by the agricultural trade associations in Kassel and found that the results were strikingly bad as compared to those reported by Scheffler[2] in Bochum By the beginning of the 14th week

	in Bochum	in Kassel
of the shoulder dislocations	67 7%	2 2% were healed
of the Colles fractures	71 4%	2 9% were healed,
of the malleolar fractures	47 4%	0 8% were healed

Thirty-five of the 137 Colles' fractures, namely every fourth one, had *limitation in closing his fist* Of 42 fractures of the radius in which the injury had occurred 2 to 25 years previously, 35 (83 6%) were receiving permanent disability payments

Of 33 malleolar fractures in which the injury had occurred 2—25 years previously, 24 (72 7%) were receiving a permanent disability pension

The results then in the agricultural injuries in 1932 were still much worse than those in Vienna in 1911

How much the number of permanently disabled from accidents and the amount of disability pensions of the injured treated in the Accident Hospital *in Vienna has decreased in the year 1927 as compared to 1911 can be seen* from the following table

Disability Payments in fractures

	After 2 years observation still being compensated		Average pension	
	1911	1929	1911	1929
Fractures of the femur	89 2%	70 0%	42 17%	29 44%
Fractures of the lower leg	80 7%	25 0%	27 39%	5 71%
Ankle joint injuries	66 8%	15 6%	14 25%	5 03%
Fractures of the humerus	78 1%	44 4%	20 50%	4 11%
Forearm fractures	62 0%	24 4%	13 08%	4 22%

The total disbursements in disability payments in 1929 after a 2 year observation period according to the figures of the department of statistics amounted to

	1911 shillings	1929 shillings	Saving in shillings
In 19 fractures of the femur	192,295	134 246	58 049
In 24 fractures of the lower leg	157,766	32 889	124 877
In 13 ankle joint injuries	106 020	37 423	68 597
In 9 fractures of the humerus	43 308	11 037	32 271
In 4 fractures of the forearm	128 707	41 524	87 183
In 124 fractures	628 096	257 119	370 977

1 Wette Handhabung und Ergebnisse des Unfallheilverfahrens auf dem Lande Untersuchungen an 303 Fallen typischer Verletzungsarten Monatsschr *Unfallheilk Heft 15/1933*

2 Scheffler Beobachtungen und Ergebnisse bei einer funfjahrigen *Frakturenbehandlung* Arch orthop Unfallchir *24* 297—380 1926

The total of all disability compensations for injured persons for 1911 would have amounted to S 15,890,129 for one year according to the statutes governing disability payments in force in 1932 For 15 years this would have amounted to S 223,351,935 Nineteen percent of this total would be for fractures of the long bones while 33% would be for hand and finger injuries

How S 8,860 in medical costs and in sickness compensation, as well as S 323,504 in disability compensation, can be saved for one individual by proper treatment is shown by the two patients with fractures of the femur of figures 3087 to 3090 In the first (fig 3087) with the much simpler *closed* fracture the treatment costs were three times as high as in the second with the severe open fracture of the femur (fig 3088—3090) In the first patient the capacity to work is permanently reduced by 50% if the situation cannot be improved by an operation The second, on the other hand, nine months after injury, has no residuals that hinder him in his work The total cost of permanent pension in the first is 190 times as high as in the second, in spite of his low annual earnings

In this regard no one can make the accusation that we are compensation-chiselers, since it would never occur to an injured person, who looks as good as the man in fig 3088 to 3090, to demand a pension because of a reduced ability to work, but rather he is happy that he is well and can again carry on his occupation

Injured persons who look like the ones in figures 3055—3066 after the termination of treatment act much differently Their condition cannot be appreciably improved even by intensive and prolonged after-treatment at a rehabilitation center They will vigorously defend themselves against a cut in disability pension, especially if the after-treatment has been painful The accusation, that we only treat the patient so that he will receive no disability payment, we now hear only rarely

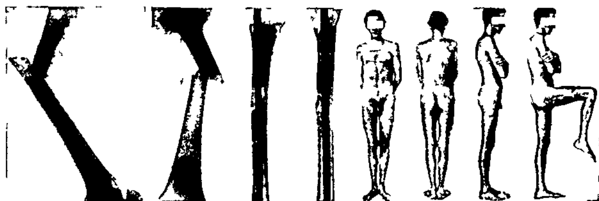
Some insurance statisticians will say that the calculations on page 2190 are incorrect That may be so in some of the details But it is not important whether the indicated savings in disability compensations are a little higher or a little lower It should only be demonstrated that the one is well and able to work which cannot be claimed for the other, and that the treatment of the one who got well was much less costly than of the permanently disabled, and that a large disability pension must be paid to the latter because of a decreased ability to work

Much more important than the saving in disability compensations and treatment costs is the circumstance that the rapidly and completely healed injured patients are returned to their occupations, that they are independent, free and satisfied and require no additional public support Much too little consideration is given to the fact that the injured patients as a rule are satisfied during treatment, but that there are only few satisfied disability recipients The economic problem is in no way encompassed by the payment for disability, since this represents at the most, two-thirds of the calculated earnings If a workman earned S 18 000 a year before his injury and then incurs a reduction of 50% of the ability to work he receives a compensation of S 6,000 a year With the remaining 50% capacity to work, however he often cannot obtain suitable



3087 September 1, 1949

FIG 3087 —Eighteen year old boy nine months after a *closed* fracture of the right femur treated elsewhere in traction with too much weight The fracture has not yet healed by bony union The leg is shortened 8 cm and angulated with an outward angle of 40° The distal fragment including the lower leg and the foot is rotated inward Up to September 1, 1949 S 58 — per day were paid by the social insurance for 172 days hospitalization or S 9976 — and S 25 — a day sick pay for 98 days or S 2540 — or S 12 426 — altogether If this condition is allowed to remain he will have a permanent disability of at least 50/ i e he will receive a monthly pension of S 541 66 or S 6500 — a year for 50 years or S 325 000 The costs for this patient then reach S 337 426



3088 September 28 1949 3089 September 28 1949 3090 Same case (Nov 14 1949)

FIG 3088 —Roentgenograms of an *open* fracture of the femur 2 hours after the injury

FIG 3090 —23 year old patient 6½ weeks after an *open* fracture of the femur sustained on September 28 1957 The wound healed without complication the bone is straight not shortened or rotated and able to bear weight Hospitalized 27 days at S 58 a day or S 1566 — sick pay for 60 days at S 33 33 or S 2000 — The total treatment costs amount to S 3566 He receives a 20/ pension or S 266 — a month for six months This amounts to S 1595 — The total cost for this patient is S 5162 —

more than 750,000 injured workers On the contrary we repeatedly hear from them at the time of admission, What will happen to me and my family when I can no longer work' And we have won their confidence when we can say to them that they can expect to be able to work again soon On the other hand, when an injured worker has to undergo a painful course of treatment, he will soon think about a disability pension

Cost Reduction by planned organization of treatment By immediately receiving the patient and by well planned treatment in the accident hospitals and accident stations as well as by applying the results of the research and teachings of the Accident Hospital in Vienna, which have been disseminated by many books (see p 2292) and by hundreds of scientific publications and lectures, the results of treatment according to the "Report of the General Accident Insurance Company for the year 1955' have been so much improved, that only 7,381 (4 84%) of the 152,346 insured industrial accidents from all of Austria are reported to draw disability pension for the first time In Vienna 2,895 (4 38%) of 65,987 reported industrial accident victims draw a disability compensation for the first time In states with insufficient organization of treatment, the number drawing disability payment for the first time is as high as 9 27%

After two years, more than half of these payments were discontinued because the condition had improved, so that only 2% remained who received permanent pensions

Insurance premiums In Austria the employer pays a flat rate for accident insurance of 2% of the wages for workers and of 0 5% for office employees This premium is considerably higher in many other countries Classifying premiums according to different types of risks has long ago been discontinued in Austria

By means of improved results of treatment it became possible for the General Accident Insurance Company to save about 400 million shillings (66 6 million D marks or 15 4 million U S dollars) for the expansion of the old and building of new accident hospitals, in spite of the fact that of the premiums of 2% paid by the employers, only 1 5% was allotted for actual costs for accidents in 1949 In 1951 this was further reduced to 1 4% for workers and 0 25% for office employees Since 1955 this figure has been 1 6% for workers and 0 5% for office employees

The premiums for all branches of social insurance are currently being collected by the National Health Insurance

In 1955 income for the General Accident Insurance Company from premiums amounted to 333 6 million shillings If the company had received 2% as formerly, instead of 1 6%, the income from premiums would have been higher by 80 8 million shillings

These 80 8 million of the year 1955 were transferred to the former insurance for invalids, now social security insurance The question may be raised whether it would not have been better to have used this sum for further expansion of the treatment program in those provinces in which the number of individuals receiving compensations for the first time is still twice as high as it is in Vienna

employment, especially at a time of increased unemployment He with his family therefore drop to a lower standard of living More important, however, is the fact that when he becomes unemployed, he must be supported by the community through the Social Insurance instead of being able to carry out his share of productive work

Financial Statement

of the expenses for treatment sick benefits and compensation in 2 patients with fractured femurs treated by different methods

The figures are based on the compensation rates of 1956 and on the resulting payments according to the laws of the General Social Insurance (A S V G)

Highest annual earnings on which compensation can be calculated by the General Accident Insurance Company (according to A S V G) (S 3600 — × 13 months) = S 46 800 —

Highest annual earnings on which compensation can be calculated by the State Health Insurance (according to A S V C) (S 2400 — × 12 months) = S 28 800 -

Full compensation equals 66 /₃/ of annual wage

Highest sick benefits per day (according to law) 50/ —60% of S 80 — = S 40 or S 50 — = S 31 200 —

1 *Closed* fracture of femur 18 years old healed with pseudarthrosis shortening of 8 cm angulation of 40⁰ and rotation (fig 3087)

172 days hospital care		à S 58 —	= S 9 976 —
98 days sick benefit pay		à S 25 —	= S 2 450 —
(based on monthly earnings of	S 1 500 —		
= an hourly wage of	S 6 25		
or a daily wage of	S 50 —		
			S 12 426 —

As result of his injury the patient ought to receive a permanent compensation of 50/ if his condition cannot be improved by operation Total disability compensation at an annual wage of S 19 500 = (S 1500 × 13) S 13 000 —
50/ permanent disability compensation is S 6500 — per year or S 541 66 per month As the patient at age of 18 has a life expectancy of 50 more years the cost of permanent compensation amounts to S 6500 — × 50 = S 325 000 —

Total S 337 426 —

2 *Open* fracture of femur 23 years old solidly united without shortening without angulation and without rotation (figs 3088—3090)

27 days hospital care		a S 58 —	= S 1 566 —
60 days sick benefit pay		a S 33 33	= S 2 000 —
(based on monthly earnings of	S 2 000 —)		
= an hourly wage of	S 8 98		
or daily wage of	S 66 66		
			S 3 566 -

Indulgence compensation of 20% for 6 months
(20% of annual earning of S 26 000 — = (S 2 000 — × 13) = S 3 466 — a year) = S 1 596 —

Total S 5 162 —

The difference in expenses between the first and the second patien is = S 332 127 —

The compensation cost for the first patient is almost 190 times higher in spite of his lower wages than for the second patient

"*Professional pensioners* The often heard claim that every injured worker only thinks of his compensation is not true according to our experience with

Some insurance carriers are opposed to the founding of new accident stations because the rates allotted for care do not cover the cost, and because for every non industrial accident there is a deficit This can, however, easily be made up when one considers that with inadequate organization of treatment many individuals drawing permanent disability pensions will materialize, of whom some will later require a total expenditure of S 300,000 and more, such as those illustrated in figures 3055 to 3066 and 3087 (pp 2176—2179, 2188)

In 1955 the accident hospitals had a deficit of about 14 million shillings This has been more than covered by the savings of about 18 million shillings in the treatment of cerebral concussion alone Besides, all other hospitals, as is well known, have a deficit of similar magnitude

The realization is gradually arising, even though slowly, that it is better to avoid severe disability from accidents by proper treatment instituted early, than to pay disability pensions

Figs 3094 to 3096 show that we had already in 1917, that is, 40 years ago, at our disposal suitable methods of treatment and an adequate organization

III THE REASONS FOR THE UNSATISFACTORY RESULTS OF TREATMENT IN ACCIDENT SURGERY

How is it possible that 50 years ago and, as figs 3055—3066 and 3078 show, in part also at present, such unsatisfactory results of treatment of accidental injuries could have occurred? The reasons are

1 Inadequacies of instruction and post graduate education
2 Inadequacies in organization
3 The application of unsatisfactory methods of treatment
4 Inadequate hospital organization and construction of hospitals
5 Inadequacies in social legislation

Inadequacies in Medical Education in General

A treatise on the revision of medical education which appeared in 1933 contains the following sentence *It is not the duty of the university to train physicians in practical matters as it is not a professional school but rather a scientific institution As such it has the duty to present the theoretical foundations of medicine to the future general practitioners In this way the medical student must often learn something that seems to be without practical significance for the present, but that can become very valuable*

I too am of the opinion that the university should not deteriorate into a professional school but, on the other hand, I have the impression that many unsatisfactory results of treatment can be traced to the fact that the students must learn too much theory and hear too little of that which they need later in their practice Practical physicians cannot be trained during the years of study The assistant years are for this purpose However, the general fundamentals could well be taught in such a manner that they are more closely related to the practice of medicine and surgery

The final purpose of the entire study of medicine must be prevention of disease and upon outbreak of disease to salvage as many lives as possible and

In addition to insured industrial accidents, the number and degree of which are accurately known, there is still a considerably larger number of accidents not related to employment and thus not included by the insurance A large number of these have severe permanent damage as the results of insufficient organization of treatment These individuals must receive proper compensation If treatment were better carried out by more adequate organization, a large part of these disability pensions could be avoided and the Compensation Insurance Fund would not be forced to rely to such an extent on that money that now comes to it from the premiums of the accident insurance It is the intention later to again give the entire amount to the General Accident Insurance Company

A small portion of the money that comes to the Compensation Insurance Fund from the portion of the accident insurance premiums, i e, 1 to 2%, should be used for *research and instruction in treatment and disability evaluation* as the best equipped accident hospital will soon fail if there is not enough research, and if the doctors are not repeatedly instructed from an accident hospital center about the newest results of the research

One repeatedly hears that it would be better to pay more compensations and larger compensations than to build new accident hospitals and accident stations Whoever has a real interest in the fate of an accident victim will see to it that he, insofar as is possible, gets well and will take precautions against his becoming, as a result of inadequate organization of treatment, a partial or a complete invalid who would receive a compensation (the value of which can become questionable, especially in times of inflation)

The accident insurance companies were formerly very unpopular, especially with the employers because they had to pay premiums and had to give information to the official who makes investigations because of the accidents, and with the workers because they often felt that their disability had been rated too low

Currently, the employers see that the General Accident Insurance Company rehabilitates the vast majority of the accident victims by its treatment procedure In addition in the case of those accident victims who are taken to an accident hospital or an accident station no investigations to determine the cause of the accident are as a rule necessary, because the manner of injury as well as the time and place of the injury, have been recorded at the time of the first examination as is described on pages 2227 and 2229

The workers are also usually satisfied because they are taken care of immediately, and the treatment, as a rule, is painless from the beginning, and because they have the feeling that they are justly evaluated when temporary or permanent disability occurs

The fact that the number of appeals of disability awards continues to decrease speaks for the fact that disability evaluation had changed and that the vast majority of the insured individuals are satisfied with the amount of the award Only 15 6% of the awards of 1955 were contested and only 3 6% were changed by the boards of appeals

When one goes through an accident hospital or an accident station, as a rule one sees only satisfied faces This was seldom the case with insured industrial accidents in former times

The laboratory work that yields so much valuable information should not be an end in itself, but rather should only be called upon for completion of the clinical examination That one cannot get to the heart of the problem with the laboratory alone, can be seen from the following example

If of five persons of varying age varying constitution and varying health specimens of every thing that can be tested in the laboratory be obtained such as urine stool sputum, gastric juice blood spinal fluid etc and submitted to the best laboratories for examination, these will hardly tell us anything about the sex and only little about the state of health, the constitution and the life expectancy When one lines these five persons up side by side however anyone will be able to tell at a glance which is young or old well or severely ill and which ones have the best life expectancy

With this I do not mean to imply that the laboratory should be completely discarded, but it should only be called upon to discover that which the clinical examination alone cannot, and that which one wants to have confirmed

The so called routine examinations as widely practiced in some countries and which investigate all of the systems of the body in very uncomplicated illnesses that are easy to recognize and that are self limited, I do not usually consider necessary

One should not attempt to teach too much The student should not be called upon to do research nor to specialize, but should rather be trained for general practice Only those individuals who are already familiar with the general fundamentals of medicine should turn to research

What results from teaching too much theory and not enough practical knowledge can be seen in an example which I experienced several years ago

A man sustained a lower leg fracture and was treated with traction by means of a Schmerz (ice tong) clamp to the calcaneus Before application of the clamp the skin on both sides was incised with a knife Since the incision was a little too large it bled slowly around the clamp The young doctor who had applied the clamp now tried to stop the bleeding First he administered intravenous calcium chloride then copious amounts of gelatine internally then adrenalin Since it continued to drip slowly in spite of these measures he called the five other young doctors who were on duty to help him They then tried a number of other hemostatic internal medications such as Stryphon Clauden etc Thereupon an injection of horse serum was given A blood transfusion was considered Since the surgeon in charge could not be reached I was called and they were very much astonished that it had not occurred to them to stop the bleeding with a small pressure dressing

All six young doctors had recently passed their examination with good grades, but they had learned so much that the simplest measure did not occur to them All the measures used could be tried if the bleeding is from a place that is not accessible for ligature or pressure dressing

When a water pipe leaks, anyone will turn off the nearest valve supplying the pipe, or if there is no valve, stop up the hole The theorist who would suggest that the leak could be stopped by artificial freezing of the water in the pipe would gain little applause

Since currently the major portion of the population is covered by *social insurance*, our practice takes place chiefly in close contact with the insurance carriers The doctors should be taught the most important principles of Social Insurance as well as how to work on an administrative basis with the insurance carriers Shorthand and typing are necessary for written communication Therefore no one should be admitted to the university who does not master these

to cure or improve illnesses and injuries in as short a time as possible and with as *simple measures* as possible

Prerequisite for every treatment is the recognition of the disease by proper interpretation of its signs and symptoms This is only possible when a suitable knowledge of physiological and pathological processes is present, i e, a good theoretical foundation

The signs and symptoms of the separate diseases and injuries are exceedingly manifold and new ones are constantly being found Since there are many signs and symptoms common to many diseases, their significance can be difficult to assess If too many signs of an illness are taught without indicating which are the most important, it can easily occur that the chief identifying characteristics are not given proper attention, while less important ones may command too much attention

It sometimes happens in the lectures that the newest results of research and disputes are emphasized, while that which one can easily comprehend with one's five senses is omitted, because it is self evident or unscientific The results of laboratory examinations are often given too much emphasis

Research and teaching must be done side by side The newest results of research, however, do not belong in the student lectures, but rather in the scientific meetings The students should primarily *hear* those things that are well-known and should *be taught* through what methods of research this knowledge was obtained

When young resident physicians report to me about pneumonia I often have the same experience namely that a series of urinalyses have been ordered that the sputum has been bacteriologically examined the blood cells counted and stained as well as various other things but that when the fever suddenly abates they forget to determine whether the pulse rate has subsided at the same time They then report that the patient is doing well and have overlooked the fact that the pulse rate has risen as an indication that the heart is beginning to fail These young doctors have learned so many signs of pneumonia that they have forgotten one of the most important things namely the paradoxical relationship between pulse rate and fever Also they have failed to note the change in facial coloring

The lectures should therefore be so presented that these signs and symptoms of illness be emphasized, that the general practitioner can recognize without all manner of apparatus, only by use of his five senses (seeing hearing touch, smelling and tasting), even if they are simple and have been known for a long time, and that one points out to him that there are still many others besides these, which are to be explored by the methods of the laboratory and need only be applied if the case is obscure

The influence of the constitution of the age and occupation on the course of the disease should be sharply emphasized

The same applies to treatment Those methods of treatment should first be taught that can be applied outside the hospital without special equipment and then others, which are only possible in the hospital or in the clinic, and in the case of many methods one should caution against using *them outside* the hospital

Rare diseases should also be shown without spending too much time on them The specialists should concern themselves with these

From January 1 to December 31, 1905, 71 fresh injuries were admitted as follows

I Fractures

1	Open fracture of the frontal bone	1
2	Basal skull fracture	1
3	Fracture of the jaw	4
4	Fracture of the humerus	6
5	Fracture of the clavicle	1
6	Fracture of the olecranon	2
7	Metacarpal fracture	3
8	Calcaneus fracture	1
9	Lower leg fracture	6
10	Patella fracture	4
11	Femoral shaft fracture	1
12	Femoral neck fracture	1
13	Fracture of the pelvis	1
	Total Fractures	32

II Dislocations

1	Shoulder dislocations	2
2	Dislocated elbows	3
	Total Dislocations	5

III Soft Tissue Injuries

1	Contused lacerations of the face	2
2	Gunshot wounds of the head	7
3	Injuries of the nose	2
4	Injuries of the ear	1
5	Gunshot wounds of the chest	1
6	Needle injuries of the abdominal wall	2
7	Penetrating wounds of the liver	1
8	Contusions of the abdomen	2
9	Contusion of the index finger	1
10	Bite wounds of a finger and of an upper arm	2
11	Gunshot wounds of palm and upper arm	2
12	Burns of the hand	3
13	Incisional wounds of the foot	1
14	Contused lacerations of the Knee	1
15	Gunshot wounds of the femur	2
16	Needles in the leg	4
	Total soft tissue injuries	34
	Total fresh injuries	71

Deficiencies in Teaching of Accident Surgery

Before the introduction of antisepsis and asepsis accident surgery took in a wide field then to recede into the background in comparison to the newly developed fields of the surgery of the great body cavities, especially the abdominal cavity

From the statistics of Billroth from the year 1869—70 can be seen that 315 accidents had been admitted to the clinic Later the number dropped still farther until it fell to 99 in a period of April 1, 1904 to December 31, 1905 when Hochenegg[1] took it over, where as we see an average of 150 fresh injuries every day

According to the annual report of Steindl[2] the injuries treated in the Second Surgical Clinic in 1904—1905 were distributed as follows

28 fresh injuries were admitted from April 1 to December 31, 1904, namely

I Fractures

1	Rib fracture	1
2	Clavicle fracture	1
3	Humerus fracture	2
4	Forearm fracture	2
5	Malleolar fracture	2
6	Patella fracture	1
7	Femoral shaft fracture	2
8	Femoral neck fracture	2
9	Fracture of the pelvis	1
	Total	14

II Dislocations

1	Shoulder dislocation	1
2	Clavicle dislocation	1
	Total	2

III Soft Tissue Injuries

1	Incisional wounds of the hand and forearm	4
2	Gunshot wound of the hand	1
3	Needle in the hand	1
4	Hematoma of the prepatellar bursa	1
5	Needle in the thigh	1
6	Bird shot injury under the skin of the knee	1
7	Effusions of the knee joint	2
8	Gunshot injuries of the knee joint	1
	Total soft tissue injuries	12
	Total of all fresh injuries	28

[1] Hochenegg Bericht aus der II chirurgischen Klinik in Wien 1904/1905

[2] Steindl Bericht aus der Unfallstation der II chirurgischen Universitatsklinik Wien med Wchschr *14* 26 27 1920

In spite of all this, accident surgery was still considered as minor surgery and the accidental injuries in many places are left to the youngest assistant for treatment

In teaching, the various methods of treatment are often presented side by side without indicating that each should only be used for certain conditions, and can only lead to a good result if it is carried out in a logically consistent manner and if not too many doctors take part in the treatment of a case (example 1, p 2163 and example 2, p 2164) It is not yet everywhere sufficiently emphasized that small improperly handled finger injuries can be as decisive for the future and the life of an injured patient as a fracture of the femur Also the questions of the influence on the psyche of the patient and disability evaluation have not received enough attention everywhere Many have commented on education in the field of accident surgery I can name for instance Steinmann,[1] Magnus, Kirschner and Burkle de la Camp

Steinmann in 1924 (p 73) wrote, "As professor Bohler has recently brought out, the treatment of fractures is currently inadequate One fourth of my practice is concerned with the corrections of conditions resulting from fracture treatment by physicians It is therefore entirely proper if something is changed here in education, etc"

Magnus in 1933 (p 288) "And what is done for the training of the doctor simply isn t enough Up to now we have not been successful in adequately imparting our knowledge to the general practitioner In this respect we have somehow failed"

Kirschner[3] 1942 (p 22) "Certainly up to now clear short instructions for traction with wire have been lacking, as well as necessary teaching centers that give the young doctors practical instructions in this field and transmit a proved tradition, since according to my experience, neither university clinics nor hospitals are basic exceptions in the incorrectness of technique of wire traction (see also Vol II/p 1180)

Burkle de la Camp[4] in 1950, in his opening address demanded better instruction in disability evaluation

Inadequacies of Organization

By proper *first aid* many human lives and many limbs can be saved Much has already been accomplished especially by the Red Cross in this field by training of lay attendents, by the organization of the ambulance service in the industries and by rapid transportation

The further fate of the injured, especially in injuries involving the skull, chest and abdominal cavities, in wounds, fractures and dislocations depends on the rapid and proper treatment by a doctor experienced in accident surgery In this field the lack is often in suitable organization In many

[1] Steinmann Verh d Dtsch Ges orthop Chir XIX Kongr S 73 1924
[2] Magnus Arch Klin Chir 177 228 1933
[3] Kirschner Randbemerkungen zur Kriegschirurgie in den Heimatlazaretten Berlin 1942 Druck des OKW
[4] Burkle de la Camp Hefte Unfallheilk 42 1950

Because of the paucity of clinical material 40 to 50 years ago, it very rarely happened that a fracture or a dislocation or some other injury was shown to the students For instance, during my six years at Medical School, I was never successful in seeing a plaster cast, in spite of taking great pains to see one Even the special lectures on fractures and dislocations were purely theoretical Several dusty specimens and old models of splints were shown *Besides, there are still today purely theoretical lectures in this field* That was the instruction for the future general practitioner But even the surgical residents and assistants who later became chief surgeons of hospitals had no opportunity to see and treat injuries in the clinic When they began their practice they were faced with an entirely new problem Many followed the traditions of the university clinics, which were reluctant to treat any injury or fracture because it tied up a valuable bed

As recently as 1917, at a lecture about the necessity of better training in accident surgery, a very well-known and influential surgeon cut off every discussion with the words "Treatment of fractures is a closed chapter, discussion of which is unprofitable One still hears similar comments about the treatment of wounds With such an attitude every advance and every stimulus to research is paralyzed, since the new clinical generation wants to and should concern itself with just those problems in which something new can be found

As long ago as 1887 Hochenegg pointed out that instruction would suffer from the increasingly felt inadequacy of accident material The statistics of the Workers Accident Insurance Company of Vienna show that complete absence of interest in accident surgery has led to fateful results for the injured individuals and thus for the entire economy

Therefore Hochenegg in 1904, when he first took over the clinic, repeatedly (as he had already in 1887 as Assistant Surgeon to Albert) urged *that the ambulance service deliver more accident victims to the clinic In 1909* he was successful in founding the two accident stations and joining them to the two university surgical clinics

Then began a new era for training and research in this field According to Steindl the proportion of accident cases that were demonstrated to the students in the clinic of Hochenegg reached 22 to 25% and the number rose during the first world war as high as 47% The students now had ample opportunity to see injuries and to learn about their treatment in the lectures and courses The accident stations for the training of residents and assistants from which most hospital surgeons stem, are especially important A whole series of methods of treatment have been developed and improved

The war with its tremendous number of injuries of the severest degree and the post-war time with its annual increase in traffic and sports accidents has awakened interest in accident surgery everywhere The trade associations under the leadership of Lohmar have exerted powerful pressure for improvement of instruction in this field Their demand for the founding of accident stations at the clinics has been carried out in most localities, and in addition independent accident hospitals were set up

surgeon now carries out his treatment on the basis of the inadequate or incorrect roentgen diagnosis (figs 3042 and 3046) and the physiotherapist should then restore the shortened and angulated bone or the joint that has healed in a subluxated position to usefulness with massage, etc (see example 4, pp 2166—2168)

In some hospitals with a pavilion system for instance, a fracture is first brought to the admission pavilion From there he is brought to the surgical pavilion Since the radiology service is located in a different pavilion, he must be taken there if the roentgenogram is to be made The radiology service is however, usually in operation for only 8 hours a day and in some places is closed on Saturday afternoon and all of Sunday After the treatment of the wound, reduction and application of the cast, another roentgenogram should be made This is, however, often not possible because of the above described circumstances of location and time Under these circumstances infections or disturbances of nutrition of the injured limb or pneumonia can develop in cold or bad weather

However, also in those places where experienced surgeons work and the physical arrangement of the service is satisfactory, poor results may be seen because unsuitable methods of treatment have been used

Use of Unsuitable Methods of Treatment

The damages that can follow fractures and that can impair function are, for example, nonunion, angulation, shortening and rotation of the involved segment of the limb, stiffening of joints, limitation of motion and pain in adjacent as well as distant joints, bone atrophy, muscle atrophy and persistent swelling

The majority of these disagreeable complications can be avoided if one consistently carries out the fundamentals of fracture treatment These are

1 Good *reduction* of the displaced fragments

2 Uninterrupted *immobilization* of the well reduced fragments with *meticulous observation of the circulation* until bony union has resulted

3 *Exercise* During the time of necessary immobilization of the well-reduced fragments, active exercise of all joints, or of as many joints of the involved limb as possible and of the entire body, *avoiding pain,* in order to avoid disturbances in circulation, atrophy of muscles and bones and stiffening of the joints

In order to evaluate the causes for the unsatisfactory healing of many fractures, one must know the methods of treatment in use, their advantages and disadvantages According to the time of their development, there are four different types of treatment, namely

1 *Immobilization* i e, treatment with *splints* or various bandages of firm material

2 Treatment by *continuous traction* The traction may be exerted on the skin by various types of adhesives (adhesive tape, Mastisol) or directly on the bone (nail, clamp or wire)

countries the injured patients are brought to the emergency stations which are open in rotation, the doctors often changing shifts every 2, 4 or 6 hours It thus happens that many of them often do not have sufficient experience

In one city of a million inhabitants I saw that the care of the accidental injuries was so organized that the operating rooms and several beds were placed in the main police building All injuries were brought there A suitable number of doctors worked there in shifts, each working from 2 to 6 hours The wounds were treated and the fractures reduced Then the patients were distributed among the various hospitals This arrangement developed in order that the police could immediately make their investigations, especially in auto and street accidents This state of affairs seems to me to be completely untenable, since those doctors who have cared for the wounds and fractures will never again see these patients and therefore will never know whether they have done their work well or not Furthermore, those doctors who take over the care of the sutured wounds and the reduced fractures cannot picture how the injury looked initially and what complications threaten *One can only acquire a true interest and a good survey of the problem if one treats an injury from the beginning to the end*

I have met a young doctor in such a Red Cross Station, who told me with pride that he had already treated 15 open fractures of the lower leg On the next day I went through several hospitals to which these patients had been transferred after their initial treatment In spite of generous administration of antibiotics many were infected

Most clinics and many hospitals have separate services for injuries Admitting the injured and putting them all in one area does not yet accomplish everything needed They must be treated by one man who had adequate experience as well as love, enthusiasm and innate ability for this specialty Doctors who do not have the ability to think in three dimensions, for instance, will not be able to treat severe fractures and joint injuries well and will never learn it

In many localities the service even now is still so arranged that the youngest assistant is given the accident station to manage and keeps it for six months or even for a year When he has acquired adequate experience to work independently, he is transferred to another service He usually gets as co-workers 2 or 3 residents who have just entered service in the clinic and have no experience They usually remain only 3 or 4 months

The shorter the time that one observes injured individuals and the less the experience, the better the results seem to be *Only he who can observe the injured individuals for years can acquire a general insight into the results of treatment*

In some localities a young and therefore inexperienced assistant, a radiologist and a physiotherapist cooperate in the treatment of fractures (example 1, p 2163 and example 2, p 2164) The radiologist reads the films, usually without having seen the patient, and therefore only too often makes an erroneous diagnosis Fractures of the carpal navicular and many serious subluxations in the ankle or the knee joint, for instance, can only be recognized, when the roentgenogram is preceded by an accurate clinical examination The

fragments using these two procedures without exposing the fracture site By means of antibiotics the risk of infection has also been reduced but not eliminated

Damage from Use of Radiography, from Traction Directly on the Bone and from Callus-Stimulating Measures

The greatest progress in the field of fracture treatment has been made in the last decades by use of radiography and by traction applied directly to the bone

Radiography Lateral displacement amounting to half and sometimes even the full width of the shaft is unimportant in shaft fractures, if the axis is good and there is no shortening or rotation For instance, lateral displacement of a femoral fracture gives no external evidence, and the usefulness of the leg is unimpaired, (Vol I/figs 261—267, 271—276, Vol II/figs 2016—2026) Since this fact is often not known, such cases have, since the introduction of radiology, often been treated operatively Sometimes then infections and other undesirable complications resulted Or repeated attempts were made to improve the position by manipulation, until finally delayed union or nonunion followed because of the continuous disturbance

How much damage can be done to a patient by incorrect interpretation of a roentgenogram is shown in example 7, page 2173

Traction Applied Directly to the Bone By traction applied directly to the bone it is easy to correct any shortening However, it is possible to pull too much This is especially hazardous in transverse fractures of the lower leg The frequent occurrence of delayed union and of non-union after fractures of the lower leg is currently usually the result of excessive traction which produces distraction of the fragments of the tibia, while the fibula unites and acts as a strut (figs 2586—2605)

Infections from pins, clamps and wires can usually, but not always, be avoided by close observation

The so-called callus-stimulating measures are indirectly the cause of many badly healed fractures, because in relying on the action of these agents immobilization is often discontinued too early and angulation, shortening, rotation and pseudarthroses occur Actually, the value of these agents is very questionable Three things are necessary to callus formation, namely

1 The stimulus provided by the bone injury
2 Adequate blood supply
3 Sufficiently long *uninterrupted* immobilization of the well reduced fragments, i e, until they have united

When these three requirements are met, even fractures of the neck of the femur or of the carpal navicular will unite

All animal experiments, that have been designed to prove the effectiveness of these callus-stimulating agents, are not conclusive because usually only young, growing animals were utilized In growing bones callus-formation is usually rapid and non-union never develops when the fragments are in good position Experiments with callus-stimulating agents would be conclusive if old animals were used for this purpose

3 *Mobilization* (early employment of massage and passive motion)

4 *Operative treatment*

One can never successfully treat all fractures with a single method Sometimes one method and sometimes another is preferable, depending on the type of fracture, the age of the patient and external circumstances (treatment at home or in the hospital)

The simplest and safest treatment is *immobilization* with splints or other firm bandages, for instance with plaster This has often been abandoned as the only method because healing with all the above described disagreeable complications has often resulted The reasons for this were manifold Some bandages were too tight and caused circulatory disturbances Others were applied without prior reduction Then healing could only occur in poor position Still others were heavily padded They were, therefore, too loose and the fragments became displaced, even after good reduction Other casts were too large and too heavy Therefore in older individuals disturbances of mobility, muscle atrophy and swelling resulted Often the bandages were removed too early Then the fragments redisplaced

Most complications *are avoidable if the fragments are accurately reduced* and held in place *uninterruptedly* by nonpadded casts that have been accurately applied and are not too heavy, meticulously observing the circulation, until bony union has occurred During the necessary period of immobilization all joints not included in the cast and the entire body should be actively exercised

Treatment in traction is principally used for unstable fractures, that cannot be suitably held in a cast, namely primarily for the femur Just in these fractures, however, shortening and angulation occur in spite of the traction because this is often discontinued too early (see example 5, pp 2168—2172) Especially severe damage follows the use of excessive traction (see Vol I/pp 26, 27)

Treatment by mobilization using early application of massage and passive motion disregards the first and second principles of fracture treatment and can only be used without bad results in fractures without displacement It is currently one of the chief causes of bad results in treatment of fractures involving joints, especially the ankle joint (see example 4, p 2167) and of the development of pseudarthroses especially in navicular and forearm fractures The damage resulting from massage is described (1) in Vol I/p 69, also (2) under each individual fracture the conditions are mentioned that can lead to complications and (3) again among the questions, that one should ask himself in order to avoid them

Theoretically *operative treatment* is the best because the fragments are accurately reduced and held by internal fixation The wires, plates and screws used for this purpose were not so strong that one could rely on them without additional plaster casts or splints In addition, the danger of infection because of operative exposure of the fracture site was very great so that often ostitis fistula formation and not at all rarely amputation or death followed This situation has been completely changed since Sven Johannssen has advocated the extra-articular operation with the nail of Smith-Petersen and since Kuntscher has introduced the intramedullary nail for the femur We can unite the

with such an array of instruments and apparatus for examination and treatment, I mention, for instance, all of the instruments for the various types of endoscopy (bronchoscopy, gastroscopy, rectoscopy, sigmoidoscopy, cystoscopy, urethroscopy), pressure — and suction apparatus for thoracic surgery various instruments for internal bone fixation (Lane and Lambotte), that it is hardly possible for one man to master the use of all of these For thoracic surgery it is not enough to have the equipment of Sauerbruch, when his long experience, his head and and his hands, as well as his large staff of co-workers are missing The same is true for the Lane and Lambotte instruments and many others Because all of these apparatuses are available, they are used, and it can happen that the mortality thereby initially increases Then it will again return to the previous level, because these too complicated instruments will be put aside

The duration of illness will hardly be shortened When the number of beds is doubled as sometimes happens with newly-built hospitals, the duration of care often increases because the patients are kept for a longer period of time in order to keep the beds occupied When the hospital becomes too large the perspective for the management and for the supervision of the patients is lost

When the resources become inadequate, economy measures are instituted The building as such must continue to be supported One can save on food and heat Then the patients are housed in airy, well-lighted rooms that are poorly heated and eat a modest fare The number of films is limited and urgently needed roentgenograms, i e, of fractures must often be omitted In the laboratories with the finest equipment the necessary chemicals and personnel are missing

How does the new hospital influence the general state of health of the population?

To live man needs food, clothing and shelter When he must pay too much tax, less remains for the simplest necessities of life He cannot eat, cannot house himself, or clothe himself as well and therefore becomes more susceptible to illness Thus it happens that the health conditions of the county are not improved by a too luxuriously equipped hospital, but rather are made worse, while a hospital that is modestly and solidly equipped and well run is an asset for the people

IV AVOIDANCE OF UNFAVORABLE RESULTS OF TREATMENT

The results of treatment would immediately be improved if it is realized that a young injured patient is worth just as much as a patient who is afflicted with a malignant tumor, tuberculosis, or tertiary syphilis While many large sanatoria and palaces with so many beds that they sometimes cannot be kept filled, have been built for these chronic afflictions, that can never be completely cured, in some localities it is difficult to find a bed for uninsured accident victims Strangely, interest for these is not awakened until they have healed with *very unfavorable results* (figs 3055—3066), which could easily have been avoided by suitable initial treatment (figs 3087—3090)

The Disadvantage of the Ultramodern Hospital

This chapter was written in 1930 and was first published in the fourth edition of this book on page 687, it is reprinted here without change

Hospital organization and construction have tremendously expanded in the last decades While there were formerly only a few hospitals, there are now well equipped institutions in every smaller city In many localities these have been furnished in such luxury, that the cities are heavily burdened with debts The pavillion system was introduced with the slogan 'Light and Air This system all too easily interferes with the supervision and with cooperation as was shown on p 2201 Under the false premise that one can heal illnesses more rapidly with money and ostentation, regular palaces with marble walls and wide halls were built Since the older hospitals had only narrow corridors or even no corridors, as the Allgemeine Krankenhaus in Vienna, and since there was an inadequacy of service rooms, the new hospitals were built with such wide halls that one could drive through them with large wagons, and the service rooms increased in size and number that beside them the patients' rooms disappear

How the general health of an area is not improved by a hospital that is too luxurious but rather is made worse, is shown by the following example

A town of 10,000 inhabitants with a surrounding population of 40,000 had an old hospital of 200 beds which had been converted from an old people's home by remodeling and addition With the income from the boarding costs of 5 shillings daily (one Austrian shilling in 1930 was worth 0 77 reichsmark or 0 20 U S dollars), the hospital could maintain itself The number of patient days was about 50,000 a year

Then the decision was made by the city and the county administration to build a new hospital with the same number of beds with modern furnishings and equipment The cost was estimated at 3,000,000 shillings

A commission was appointed, which studied domestic and foreign hospitals for six months in order to learn about all advances in the technique of building, furnishings and in instruments and apparatus Whatever was beautiful and expensive and had proved useful in the foremost specialized institutions was ordered At the opening of the new hospital it developed that the cost had risen to 6 000,000 shillings

Because of the enlargement of the rooms the personnel had to be doubled The costs for light and heat increased by five times, so that a patient day now costs 12 shillings The 6,000,000 shillings commanded 8% interest, which amounted to 480,000 shillings annually or for 60,000 patient days to 8 shillings per patient day Thus a patient day no longer costs 5 shillings as formerly, but 20 shilling The city thus must pay in addition 15 shillings per person per day or 750,000 shillings This amount of money can only be raised by taxes

Now the question arises what advantages have been achieved by the construction of this ultramodern hospital?

Every hospital has the mission to reduce mortality and morbidity When we investigate wheter this has been more successfully accomplished in the new hospital, we will find that this is not the case The new hospital is furnished

with such an array of instruments and apparatus for examination and treatment, I mention, for instance, all of the instruments for the various types of endoscopy (bronchoscopy, gastroscopy, rectoscopy, sigmoidoscopy, cystoscopy, urethroscopy), pressure — and suction apparatus for thoracic surgery various instruments for internal bone fixation (Lane and Lambotte), that it is hardly possible for one man to master the use of all of these For thoracic surgery it is not enough to have the equipment of Sauerbruch, when his long experience, his head and and his hands, as well as his large staff of co workers, are missing The same is true for the Lane and Lambotte instruments and many others Because all of these apparatuses are available, they are used, and it can happen that the mortality thereby initially increases Then it will again return to the previous level, because these too complicated instruments will be put aside

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In order to achieve better results in accident surgery, one must first establish What are *unavoidable results of the accident* and what are *avoidable results of treatment?*

It should here be repeated that limitations of motions of the fingers after *closed* fractures and other injuries of carpal bones, the forearm, the elbow or the upper arm and the shoulder girdle, or limitation of motion of the shoulder after injuries from the elbow down, the frequent *pes equinus* after injuries in the region of the leg, traumatic flatfoot after fractures of the malleoli, shortening of more than 2 cm after closed fractures of the femur or lower leg and angulation of more than 10° almost always and spreading infection, i e, not limited to the area of open injury — usually are *avoidable complications of treatment* and not unavoidable results of the accident.

In injuries of nerves, muscles and tendons, active motion can be restricted or absent, even if the joints are passively freely mobile.

As soon as these facts have been accepted and are generally recognized, it will be necessary to answer the question in the individual case what the cause of the unsatisfactory results of the treatment has been and who bears the responsibility.

In order to avoid the unsatisfactory results of treatment in accident surgery, the *instruction, organization* and the *hospital attitude* must be changed and the use of unsuitable methods of treatment must be eliminated.

Changes in Teaching in High School and College

Certain written records are absolutely necessary for the history, diagnosis, treatment, and especially for disability evaluation. These can be most quickly done in shorthand and be preserved and forwarded in legible typed form. Currently some of the doctors can neither write shorthand nor type. Surprisingly many decline to avail themselves of free courses in these subjects that have been established because they would thus become bureaucrats.

In addition, everyone should know how to write a formal letter, a report or a request, and that the date, as well as the legible name and the address of the writer, should be included. In higher schools these subjects are not offered, because it is feared that one would thereby implant into the students a mercenary outlook. It should be pointed out in this regard that the classical Romans, the greatest organizers of ancient times, whose writings we have read for eight years, have written or chiseled their dates on everything. It also would do no harm if doctors would learn the simplest rudiments of bookkeeping.

In my opinion, no one should be admitted to the university who has not mastered shorthand, typing and the writing of an *ordinary composition*. It should be added that knowledge of modern languages is always useful.

Changes in Instruction in Accident Surgery

In recent times, much has been written about who should teach and give examinations in *accident surgery* and where in the teaching program the time can be fitted in.

Since well over 90% of the injuries are purely surgical, treatment of injuries is primarily a surgical matter Accident surgery, which must embrace the mechanism, diagnosis, after treatment and disability evaluation, should therefore be taught by surgeons, or if they do not have the necessary time, by special accident surgeons In this respect it is especially important that the accident surgery of the extremities be not separated from that of the trunk and head, since especially in traffic accidents it is becoming more and more common for a person to sustain simultaneous injuries of the trunk and extremities The accident surgeon must be able to perform skull trepanation, tracheotomy, suture of the heart, of the gastrointestinal tract, the urinary bladder and ureter as well as splenectomy or nephrectomy

In order to be able to carry out the after care, which begins on the day of the injury, he must be trained orthopedically For diagnosis, treatment and disability evaluation considerable experience in the *radiology of bones* is required The accident surgeon must master this segment of roentgenology Since industrial accidents are insured and traffic injuries often lead to damage suit (in sport accidents this seldom occurs), he must be conversant with the *legal aspects* in this field Here also, some doctors refuse to take courses in this subject and completely forget that the greater part of the population is covered by social insurance and that we had no less than 788,000 persons receiving compensation from the social insurance organization in Austria at the end of 1956

The accident surgeon is thus not a new type of specialist in a branch of medicine, but rather he should master that which is necessary in order to treat the injured from the beginning to the end, and at the end, to evaluate his disability He also should carry the entire *responsibility* for the treatment alone There should not be further division in medicine, but rather a synthesis What results when too many specialists take part in the treatment of a patient is shown in example 1, page 2163 and example 2, page 2165

Injuries of the eyes and ears should be reserved for these specialities, and for diagnosis and disability evaluation specialists should also be called upon, especially the neurologists and internists

The question is repeatedly raised from where the time should be taken to each accident surgery As has been *indicated* on pages 2196—2199, *it* was given little consideration 50 years ago I believe that the time that should be devoted to a subject in teaching should be directly proportional to its importance to the national economy The number of injured is greater than the number of all individual diseases Since injuries lead all reported illnesses (see p 2182) that cause loss in working days, with their financial impact for the patient as well as for the community, the *time required* for instruction in this subject must be made available

In the main industrial accidents involve individuals who are otherwise well and who would have to be supported by the community, if the result of treatment is inferior and permanent disability remains (figs 3055—3066) Adequate treatment, which always creates less expense than inadequate treatment, returns the injured to work soon without disability (figs 3088—3090)

These facts prove the great significance and the necessity of proper teaching of accident surgery

The amounts paid for treatment and disabilities could in my opinion, easily be reduced to half or even to one-third by adequate treatment and organization This would be possible in 5 to 10 years by a thorough revision of education and organization

For instance fracture dislocations of the ankle could be completely restored in at least 95% of all cases in 3 to 5 months with simple measures and minimal expense while with inadequate treatment they remain 30—40% permanently disabled Tuberculosis of the ankle joint on the other hand requires 2 to 3 years to heal and incurs great expense during this time in sanatorium care etc and the final result can never be a normal joint

According to our experience, one-third of the injured have wounds Therefore instruction in the treatment of wounds should be accorded the greatest attention

In the treatment of wounds it must be taught that infections cannot be avoided by chemical or serological measures, but primarily by surgical measures, namely by meticulous wound excision and primary suture of the skin as Friedrich has taught, and by *following* this with uninterrupted immobilization The antibiotics are a valuable aid in the treatment of wounds, but they are not essential They are currently being used too much The student must however, at the same time, be cautioned about the great dangers of wound suture with inadequate wound excision and he must be taught by demonstration of good and bad examples, what cases the general practitioner can take care of himself and which ones he should refer to a specialist or to a hospital as quickly as possible He must be shown that in every fresh wound the result depends on its being excised as soon as possible and sutured under suitable circumstances, since after six hours the prospects for primary wound healing are poor and that open bone and joint injuries can lead to death, amputation or severe permanent disturbance if infection develops, and that by delayed arrival of the patient, he bears a large part of the responsibility He must also be shown that after avoidance of infection, the result depends not only on achieving primary wound healing, but also on rehabilitating the injured part by *painless* exercise The injuries should not only be surgically, but also functionally healed

Questions and answers in accident surgery should be as simple as possible

Exercise When an injury of the arm is to be treated, the result depends only on the restoration of mobility of all joints as well as the former strength In injuries of the leg it is of primary importance to restore the stability and the ability to bear weight painlessly and then also the mobility of all joints as far as possible In injuries of the spine the aim of treatment should be the full ability to bear weight and normal elasticity Chemical serological and bacteriological examinations are interesting in this regard but should not assume such importance that the most elementary things are forgotten It is not reasonable to determine the calcium level of the blood in an ordinary fracture of the radius and at the same time allow the fingers and shoulder to become stiff

If one requires the movement to their full range of all joints that have not been immobilized, they can never become stiff and after-treatment is as a rule superfluous

In the lectures numerous fresh injuries should be demonstrated and their treatment critically discussed One should warn against inadequate treatment methods and for other methods it must be emphasized that in the hands of an experienced man in a well equipped hospital they produce good results, while they may cause serious damage when they are applied by an inexperienced individual To acquaint the students with the course and duration of healing, all patients should again be shown in the next days or weeks and, without exception, at the end of the semester In addition to every fresh case, older cases of a similar type with good and bad results should be presented for comparison In this way all complications and the cause for their development, their avoidance, the duration and the cost of treatment and the social impact on the patient and his surroundings can be discussed, *but never in the presence of the patient*

Occupation, constitution, condition of health at the time of injury (arthrosis deformans, osteomyelitis, tuberculosis), and age are particularly to be considered in instruction It must always be emphasized that patients who are over 40 years old and are of the pyknic type tend especially to disturbances of mobility and that for that reason the mobility of their extremities must be tested daily, and that certain types of arrangements of casts such as volar flexion at the wrist or the application of a volar splint extending to the finger-tips (see example 1, p 2163) will lead to severe disturbances, while youthful joints that have not previously been severely damaged by an injury or illness cannot become stiff even by unsuitable position or prolonged immobilization, *if the joint itself has not been damaged*

The difference between *unavoidable results* related to the accident and *avoidable complications due to treatment must be sharply emphasized and it should clearly be stated that the doctor also is responsible for treatment complications*

Often the interest that is given a patient is related to the size of the fractured bone or the extent of the soft tissue injury This is not justifiable as it makes no difference to the patient who, for instance, cannot work for six months, whether this occurred as the results of a severe fracture of the femur or of a neglected, inadequately treated wound of the little finger

The role played by finger injuries is described on page 2187

Man is composed of body and soul These are inseparably linked together In every illness psychic influences play a significant role, and in insured industrial injuries these are especially prominent Hardly half of the treatment of accidental injuries and fractures is a mechanical (surgical = handwork) problem The reduction of the fractures and the continuous immobilization of the fragments until bony union has occurred, is a technical-mechanical problem and a prerequisite that cannot be circumvented if good healing is to be obtained The carrying out of painless exercise which should begin immediately after reduction even during immobilization of the injured parts, is a psychological problem Therefore, the role of psychotherapy for insured

industrial injuries must be emphasized and taught. Careless remarks about the result of an injury (see example 7, p. 2173 and example 8, p. 2174) should be painstakingly avoided. One must ask every patient his name, his occupation and his standard of living (size of the family, etc.). When his doctor knows these things, he will gain the confidence of the patient. Novocaine and plaster belong to the best psychotherapeutic agents, i. e., eliminating pain from the first moment on and during the entire treatment and *after-care*. In addition, suitable surroundings are important. If, for instance, a patient with a fracture of the spine is placed in a room in which there are other injured patients who do gymnastics and carry sand bags on their heads just a few days after their injury, he will immediately wish to equal them or to outdo them. If, however, he must lie for months in a Glisson sling or in a plaster shell and must look at other patients, who still after years wear orthopedic braces, he only thinks of his broken backbone. He also loses his moral 'backbone' and becomes a compensation neurotic.

It is also important to convince the injured patients that their limbs and their body belong to them and not to the community, that they *themselves are responsible for them*.

In regard to so-called major surgery the diagnosis and indication for surgery, especially in acute cases, is most important for the general practitioner. The exact technique of the various operations, a subject which is sometimes given too much time in the lectures and examinations, is of less value for him. These matters concern only the small group of surgical specialists.

What the future practitioners learn and should already be practicing as students, next to first aid and the treatment of shock, is so called minor surgery, the diagnosis and initial treatment of fractures and dislocations and the avoidance of wound infections after open injuries, while the major interventions in accident surgery should be reserved for the specialist.

The introduction of an accident surgery interneship similar to the obstetrical interneship is recommended.

In 1933 appeared the publications of Lohmar and of Fischer. Lohmar authored a well thought out proposal which was submitted to the proper ministry on January 14, 1931 by the trade associations, and which emphasizes everything that is important for the instruction and training of doctors in this field. In addition he has described in a clear and concise manner how the trade association accident treatment procedure is regulated in Germany.

The Workers Association for Accident Medicine was formed as the result of the stimulus given by Lohmar. By interchange of ideas they promote the further training of accident physicians and of directing administration officials.

Fischer emphasized that instruction in the universities must be tailored to the training of the general practicioner, but that further burdening of the students with new subjects is not possible, because the schedules are cluttered with lectures that in a large part are superfluous for the general practitioner (see p. 2212 bottom).

Changes in Organization

The treatment of accident victims must be so organized, that in every single case a single doctor from the beginning carries the *responsibility* for the entire treatment and for the end result, even when various assistants work under him It should not happen, that the patients are treated in a unit for urgent surgery by wound excision and reduction of fractures and are then transferred on for further treatment, as is described on page 2200

One repeatedly finds that patients pass through several hospitals, insurance carriers and social service institutions In addition to many other deficiencies this has the great disadvantage, that there are relatively few doctors who are informed about the final results of their treatment which is only a partial treatment (see example 1, p 2163 and example 2, p 2164) The accident insurance carriers are a well known exception Since they are responsible for the pensions in permanent disabilities, they make every effort to fully rehabilitate the injured workers, in so far as is possible, while the State Health Insurance Association is chiefly concerned with getting them off the sick list as soon as possible in order not to have any further expenses

Who should treat those injured in accidents? Only he, who, as the result of his training, has the necessary ability and is in a position to avoid the treatment complications listed on page 2162 and can therefore take over the entire *responsibility* from beginning to end

The viewpoint still held 50 years ago that the treatment of accident victims is unworthy of the better surgeon and that one could leave these to the least experienced resident and the attendants, has today been overcome in most places and, as the literature of the last few years shows, the publications about the treatment of injuries in general and of fractures and wounds in particular again occupy a large place

Not long ago it was still taught in many places, that the general practitioner could and should treat every fracture and wound that does not involve the inner organs In fractures, as long as one was satisfied to apply any kind of a splint for as short a time as possible and then to begin energetic massage and apply an ointment in fresh wounds, this attitude was understandable The results that were thus achieved, as the statistics on pages 2185—2189 show, were understandably not favorable In the meantime we have learned that one does not only splint and massage fractures, but that they should first be reduced and with simultaneous painless exercise, held immobile uninterruptedly until bony union has taken place, and that one can best safeguard fresh wounds from infection by primary wound excision, use of antibiotics, suture of the skin and immobilization by simultaneous painless exercise

Since certain aids are necessary for the reduction of serious fractures, and X-ray apparatus for the control of the position, and surgical training and suitable facilities for wound excision and suture, it is better if the general practitioner refers the serious cases to a hospital The minor injuries on the other hand, which represent about three fourths of all injuries, he can and should treat himself The border between minor and serious cases will vary according to the training and ability of the general practitioner, and with

better training and equipment he will be able to take care of more and more cases himself

Lohmar[1] has worked out a complete scheme for the accident treatment program for the trade associations in which all cases are listed that the general practitioner can handle himself and those that he must refer to a specialist or a hospital

Some hospitals are, even today, not equipped to treat severe injuries, since neither a qualified doctor nor suitable equipment is present Thus it occurs that fractures and other serious injuries do not heal better in the hospital than at home As soon as the general practitioner has had this experience he will keep some serious injuries at home, since the uninsured avoid the costs of a stay in the hospital

Collective treatment in which several general practitioners and specialists are associated in the care, one after another, each without knowing anything about the treatment by the others, and without anyone bearing the *responsibility for the final result,* must be stamped out (see example 1, p 2163 and example 2, p 2164) No matter how capable each individual doctor is in his specialty, this working collectively can lead to no good

Apparent care It is only apparent care when some insurance carriers emphasize that they can place all specialists at the disposal of every one of their members Even a well person cannot always stand too much care The result does not depend on doing much and doing many things (see example 1, p 2163), but rather that one carry out every treatment as simply as possible, that one carry it out logically and that one man *bear* the *complete responsibility*

When first aid in open wounds consists of excising and suturing the wound and then sending the patient elsewhere without knowing who is taking over the care this also is *apparent care* (see page 2200) Only he may excise and, under favorable circumstances suture, a wound, who, according to the external conditions, will also be in a position to take over the further care and the *responsibility*

I have seen the worst spreading infections that sometimes led to death in those cases that had been sutured somewhere and then transferred elsewhere Sometimes in such cases I have found foreign bodies deep in the wound and sometimes the cause of the severe complications could not definitely be determined However, the person who had first cared for the wound was always convinced that he had done a good job

Is it not also *apparent care* when a man with a congenital lumbar rib is furnished with orthopedic braces by three different units (see example 7, p 2173)?

Roentgen Procedure If the accident unit does not possess a roentgen apparatus, the radiologist may only render a diagnosis if he has personally examined the patient clinically, or when the surgeon gives him the clinical findings of the injury (see example 3, p 2165, example 4, p 2167 example 7, p 2173

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[1] Lohmar in Konig und Magnus Handbuch der gesamten Unfallheilkunde Vol II Stuttgart Verlag Enke 1932 p 418

and example 8, p 2174) It is better for the clinical and radiological examination to be in the hands of one man

Services for the Treatment of Septic Wounds If infection develops after open injuries, the patient may not be transferred to a septic ward which is in charge of another doctor Many a surgeon would have operated on fewer closed fractures, if he would have been forced to see those cases daily for months, in whom an infection developed, and if he had had to evaluate their disability after months

The accident surgery rehabilitation center which also provides the further care for the serious cases should not be under independent direction, but must be under the supervision of the surgical director of the accident service Only in this way is it possible for the accident surgeon to remain informed on the continued progress of the injury

Disability Evaluation In order that the accident surgeon remain informed on the further fate of the injuries treated by him, he should also evaluate their disability If the disability evaluation in insured industrial accidents is done by another, the doctor who has carried out the treatment should continue to be informed as to the result

Accident Surgery and Orthopedics In some localities it might be best to combine orthopedics with accident surgery, as has already taken place in part in America, Italy, France and England

Accident Services without Independent Direction It is also not worth while to establish too many accident stations in one area if not enough trained assistants and personnel nor enough beds are available The control is then lost in the individual case I have discussed shoulder stiffening after finger, hand and forearm injuries with a surgeon through whose clinic 70,000 accident victims had passed in the course of 12 years He explained to me that he had never seen this serious complication He admitted, however, that he seldom visited the out-patient clinic that was attached to the clinic, and that the assistants who conducted the clinic were rotated every three to four months and were therefore also not informed about the complications

The equipment of an accident unit should be as simple as possible and still contain everything necessary An aseptic operating room, a septic operating room, a cast room and a roentgen room are essential These four rooms should be next to one another A mobile X-ray unit is indispensible The roentgenograms should be stored adjacent the roentgen room so that the films of the last year are immediately available The films should be arranged and inscribed in the manner shown in Vol I/pp 90—92 In addition, traction apparatus for the reduction and further treatment of fractures, and frames should be available in sufficient number for supporting the extremity in various injuries of the arm and leg

After-care Special after-care is no longer necessary for most patients if the initial treatment has been suitable One can easily get along without apparatus for passive movements and other complicated machines Several pulley apparatus with sand bags rings to pull on, spring dumbbells and rubber balls, several heat cradles and a diathermy or short wave therapy machine are

usually sufficient to carry out the entire after-care Most important is always the active *painless* exercise

Rehabilitation Centers Amputees and severely handicapped individuals should be transferred to rehabilitation centers, where they can be schooled in the use of their artificial limbs and retrained Here they should have the opportunity for swimming, for other sports and especially for work

Lohmar has set about the same *requirements* for the accident treatment program of the trade associations

Conducting the Accident Unit Since about one third of all injuries arrive with wounds that can lead to severe infections, amputation and death, wound treatment should be accorded particular emphasis By primary wound excision, use of antibiotics, careful suture of the skin without tension and uninterrupted immobilization, progressive infections can almost always be avoided, if it has been possible to receive the injured individuals for treatment within the first six hours With the exception of remote mountain valleys, this aim can almost always be achieved with proper insight and effort, since most larger towns have ambulances available Duty must be so arranged that constantly, day and night, a doctor who is experienced in wound excision and suture is on duty with sufficient personnel According to Ehalt,[1] primary wound healing can be achieved in more than 86% of open fractures and in soft tissue wounds in more than 96% of all cases

Closed dislocations should immediately be reduced, in closed fractures this is absolutely necessary if a fragment threatens to penetrate the skin or if a joint is involved After wound care and reduction of the fractures and dislocations the responsible doctor must check the free mobility of all uninvolved joints or have this reported to him Thus one avoids disturbances of mobility and after-care usually is not necessary

The roentgen apparatus must always be available, even at night and Sundays

Economic Organizations of Doctors and Accident Surgery The aim of these organizations is to safeguard the economical interests of the doctors, for instance, by contracts concerning payment of salaries and fees In recent years the stand was taken that all doctors are equal in all respects This is, however, by no means true Severe fractures can only be treated by those who have the ability to visualize things in three dimensions If they are not able to do this, the longest training is to no avail Such doctors may, however, have great talent in other branches of medicine

The medical associations should themselves be concerned that the doctors are better trained in *these fields* and those who often experience avoidable complications of treatment be excluded from the treatment of injuries, according to the old maxim *Salus aegroti suprema lex* The respect for the medical *profession will thus increase in the eyes of the community*, and quackery, which is still very widespread particularly in the field of treatment of injuries, would disappear

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1 Ehalt Behandlung der offenen Bruche der langen Rohrenknochen Wien Verlag Maudrich 1938

In order to basically improve the results of treatment, the branch of accident treatment must be made independent In every hospital that has more than 100 beds, a separate service for accident surgery with a completely independent superintending doctor, with separate operating rooms, separate roentgen room and separate patient rooms should be established In addition, separate space, needed for aftercare as well as disability evaluation, should be included

In cities of more than 100,000 population a large independent accident service with 150—200 beds should be organized in a large hospital or an accident hospital should be established Cities of more than 100,000 population usually have a drawing area of an additional 50,000 to 100,000 inhabitants Usually several hospitals of from 50 to 400 beds are available for these 200,000 people The proportion can vary somewhat The total number of beds is 1200—1600 Of these, 400—500 are surgical The distribution of the injured patients to the various hospitals is such that either the city is divided into zones and the patients are brought to the nearest hospital or that every day a different hospital admits accident victims

With these two methods of distribution it is utterly impossible, taking into consideration the numerous traffic accidents, that enough doctors are available in every hospital nights, Saturdays and Sundays, who have sufficient experience in this field The radiology department is also not available Since it would be uneconomical to arrange in every small hospital for night dutv and X-ray duty for several doctors and technicians, and to have available the necessary traction — and supporting apparatus, it would be best to furnish one of the hospitals as an accident hospital or to open a completely independent accident service in a large hospital All injuries can be taken there This then *insures* that everything is always *on hand* in the way of doctors, technicians and equipment that one needs for a difficult case No significant expense arises for the city administration, since one is concerned only with a different distribution of existing beds The beds, the rooms and the personnel would not have to be significantly increased if all accidents were treated in one place In fact, the expenses would get less, because the time of healing is shorter with well planned treatment (see p 2190 and figs 3087—3090)

The directors of these hospitals or independent accident services would have to be specialists in accident surgery who have also mastered general surgery, since sometimes not only soft tissues and bones, but inner organs are also injured The accident surgeon must also be familiar with skull trepanation, tracheotomy, suture of the heart, the gastrointestinal tract, the bladder and ureter, splenectomy and nephrectomy In order to be able to carry out the aftercare that begins already with the day of the accident, he must be *orthopedically trained* For diagnosis, treatment and disability evaluation extensive experience in the field af *bone radiology* is necessary The accident surgeon must therefore master this branch of radiology Since most accident victims are somehow insured, he must be familiar with the legal aspect in this field The accident surgeon should not then be a new specialist for one organ, but should rather master all fields necessary in order to treat a patient from beginning to end and finally to evaluate his disability, so that

he does not have to be sent around to various doctors He should also bear the entire *responsibility* for the treatment alone The treatment should not be shared with the general surgeon, the radiologist, the physiotherapist and the disability evaluator, who often have little connection with one another (see p 2163—2174)

In the hospitals of the smaller towns and the rural districts, the chief surgeon must have at least 2 years training in accident surgery in an accident hospital or an accident station It would be preferable if a specialist in accident surgery were employed

With this organization also the young doctors would learn the most in this field for their later general practice, and they will know exactly which *injuries they can care for themselves* and which they *must refer*, because of inadequacies of equipment In order to develop adequately trained doctors for the supervision of the accident hospitals and independent accident stations, separate *university clinics for accident surgery and disability evaluation* must be created which in some places will be suitably combined with the orthopedic clinics

We do not mean to say that the general surgeons are not also in a position to treat injuries well Some have already proved this In the last 30 years several thousand surgeons have visited me from all countries of the world Most of these have said that they did not have the necessary time to excise all wounds so meticulously and then to immobilize them as we are accustomed to do, or to reduce the fractures until they are in good position Most of them experienced particular difficulties because they were dependent on a centralized radiology service So many demands are often made on the general surgeons by their urgent operations especially through the acute illnesses of the abdominal cavity and therefore to their regret they cannot dedicate themselves to the problems of accident surgery to the extent necessary

Objections to the Independence of Accident Surgery The claim is repeatedly made that the further divison of medicine must be prevented This was already the case when ophthalmology, gynecology, obstetrics, ear, nose and throat, urology, orthopedics and others split themselves off Today no surgeon would consider personally taking care of eye diseases In accident surgery we are not concerned with a further division but rather a contraction A man should dedicate his full ability to the treatment of the injured patients in order to rehabilitate them as far as possible, that is, in so far as they do not have unavoidable sequelae of injury

Many object that minor surgery (as they call accident surgery) should split itself from so-called major surgery The ' major ' and 'minor no doubt refers to the difficulty of the operation I would rather consider them on the basis of their economic significance The most difficult interventions of general surgery are the cancer, brain lung and heart operations The mortality associated with these procedures is very great and the economic advantage as a rule small When, on the other hand a young worker gets a useless hand as a result of a small wound on the thumb (see fig 3055), this represents a major catastrophe, not only to the patient, but to the economy Furthermore in accident surgery there are technically difficult interventions in large numbers

I will only mention nailing of femoral neck fractures, arthrodesis of the hip, operations for pseudarthroses, the various tendon and joint plastic procedures, etc

Since in my writings of 1917 I requested the establishment of special services for gunshot fractures and gunshot wounds of joints and suitable instruction, and in 1919 the establishment of accident hospitals and of independent accident stations and in 1942 the establishment of independent university clinics for accident surgery, all opponents always voiced the following two objections

1 The accident surgeons will not be in a position to treat injuries of the skull, thoracic and abdominal cavities, and these patients will come to harm through independent accident hospitals and accident stations

2 The students and general practitioners no longer have an opportunity to learn accident surgery properly

1 *Surgery of the Body Cavities* In 1948 the blunt injuries of the abdomen of the Vienna Accident Hospital were reviewed by Slany[1] He found that this was the largest series of this nature that had been published up to that time and that the results were better than in the surgical clinics According to the research of Poigenfurst the results have become still better in the last nine years This is proof that abdominal injuries can also be treated suitably in accident hospitals If however an accident surgeon in a smaller independent accident unit of a general hospital does not feel capable of treating an abdominal injury, it is very easy to transfer it immediately to the surgical service, i e, one floor higher or lower The accident surgeon then has only the problem of making the diagnosis

The approximately 1000 skull fractures of the Vienna Accident Hospital are being reviewed now According to a brief survey the results seem to be surprisingly good

2 *Teaching of Students and General Practitioners* It can be assumed that accident surgery can be taught better in those places where it is exclusively practiced than in those where it is only of secondary interest

If one reads the figures on page 2190 and views figures 3055—3066 and 3087—3090, one will then be astonished that in the year 1957 there has still been so much opposition to accident surgery

According to our current concept of the principle of efficiency in medicine, we should first inquire about the economic importance of an illness or injury and we must then conclude that accident surgery occupies one of the first places because it can largely limit the permanent damages that were up to now common and that lead to reduction of the capacity to work But not only economically, but also numerically, the number of persons injured in accidents is much greater than the number of sick people in other specialities (see p 2182) Some diseases are markedly diminishing as a result of hygiene and especially use of antibiotics for example, orthopedics, ophthalmology and venerology

[1] Slany Stumpfe Bauchverletzungen Wien Verlag Maudrich 1948

The field for work in orthopedics which has as its task the correction of congenital and acquired deformities, is fortunately becoming smaller, because bone- and joint tuberculosis, rickets and poliomyelitis have diminished because of preventive health measures, and because by the avoidance of the treatment complications the number of acquired deformities will sharply decrease By better nutrition and elimination of chemical and mechanical trauma during pregnancy prenatal damage too will be avoided which could lead to congenital deformities

The number of illnesses in the field of ophthalmology has very quickly diminished Surveys of the ambulatory cases of the last 35 years have for instance shown that ocular tuberculosis has decreased by 90%

The number of accidents on the other hand has increased tremendously and will continue to increase (see pp 2180, 2181)

Formerly many objections were raised, and are still being raised today, that we have no money to equip new accident services and accident hospitals If the results of treatment can be improved by spending money, then costs cannot be counted In this case, however, we need very little money, because primarily only a redistribution of beds, rooms and personnel are required However, even the costs for new buildings are paid by the savings in compensations (see p 2190) and by shortening the treatment time, so that we can make savings all along the line by the new arrangement

Many say that we do not have enough doctors trained in this field for running these accident services and accident hospitals This also is not true, as even now there are many assistants who have been trained for years and are still being trained in the existing accident hospitals and accident stations

It is peculiar that just those individuals claim that no well suited doctors are to be found for the directorship of independent accident stations who have up to now assigned the treatment of the injuries to their 1st Assistant

If, however, there are actually not enough trained doctors available in this field, they must be trained in independent accident clinics

The objections that Steinmann (see p 2199) made to my presentation "The Training of Doctors in Accident Surgery' at the 19th Orthopedic Congress in Graz are very interesting He said "It will still be a long time before the functional treatment of fractures is generally understood by doctors Fracture treatment is currently inadequate as Professor Bohler has stressed anew One fourth of my practice consists of corrections in fractures treated by doctors It is then entirely proper if something is changed here in instruction Now my colleague Professor Bohler suggests that independent accident hospitals be established This is certainly proper if we place the interest of the patient in the foreground To my way of thinking we must however take a wider view Because if we establish too many accident hospitals and send all fractures to them from the beginning, then we will remove the entire fracture treatment from the general practitioner I ask myself, Where will the doctors then have the opportunity to maintain their proficiency in fracture treatment? The entire important field of fracture treatment will be withdrawn from them That means for the general practitioner, as Liniger has already stated, the loss of a large part of his income, such a blow that the

medical profession will not be able to maintain itself. It would have been better to so instruct the doctor in the treatment of fractures, that he could keep a part of them. However, this procedure would encounter great difficulties, because the doctors themselves little realize that they are much lacking in this respect. It would probably be best, if accident services would be established in the university clinics, and if in them fracture treatment would be taught by means of practical demonstration at the bedside. Today the doctors leave medical school inadequately prepared in this respect."

I believe that those concerned with health will take the stand that the interest of the patient must remain in the foreground. Besides, when the general practitioners have had the opportunity to obtain further training in a university clinic for accident surgery, in an accident hospital or in an accident unit, they then will be able to treat many injuries, including some fractures themselves. I know from my assistants, that there, where they have started as general practitioners, quacks and bone setters soon disappeared without any action on their part but just because they get better results, whereas formerly all intervention of the authorities and all law suits did not help. As general practitioners and sports doctors they treat even severe fractures in large number.

Many warn against exaggeration of treatment. When we look at Vol II/figures 2159—2164, we can talk of a peak achievement. The treatment of this patient was not overdone, but rather quite simple. The wounds were cleansed with the knife, the fracture was reduced and immobilized with traction and the joints were actively exercised. It was thus possible to achieve a complete restoration to normal in the shortest possible time. A similar result is shown in figures 3088—3090.

A well planned *health system* will insure that the avoidable complications will in the future be reduced to a minimum not only in the insured industrial accidents, but also in the traffic and sports injuries. Where avoidable treatment complications appear frequently, the causes will be investigated. The individual doctor will not be charged with being at fault, but rather the conditions of his environment will be examined and it will be found that these did not allow him to do better work. On closer scrutiny, it will be discovered that first aid and transportation are not adequately organized, so that the injured persons arrived too late for treatment, that the doctor did not have enough time because he was concerned with other problems, for instance, that he was overburdened with urgent general surgery, that not sufficient roentgen or traction equipment was available, that he did not have enough trained personnel and that he used outmoded methods that must lead to bad results because he had not learned any others. When similar investigations of frequently occurring *avoidable treatment complications* repeatedly uncover the same causes, the *health system*, to be consistent, will correct these inadequacies and will come to establishing independent accident services and accident hospitals with independent medical directors, their own operating rooms, roentgen rooms and patient rooms. A service for industrial diseases will be connected with the larger accident hospitals, where the serial examinations necessary to their prevention can be carried out and the already afflicted can

be cared for In the rural areas in which the hospitals are too small for independent accident units that *health system* will at the time of filling vacancies hire only such doctors who are especially well trained in accident surgery Then it will no longer happen that in localities with larger industries or in traffic hubs with numerous traffic accidents wounds and fractures are not cared for until the following day, or that femoral fractures only exceptionally heal without permanent damage, or that stiff hands and fingers are frequently seen

In order to train students and general practitioners still better in this field *independent university clinics for accident surgery and disability evaluation must be established in every university* There the future directors of accident stations and accident hospitals can be trained In addition, accident surgery must become a separate subject in which examinations are given [1]

In a six year program it would easily be possible, after the establishment of the university clinics for accident surgery, to train enough doctors and to establish the independent accident stations and accident hospitals Then we will have enough treatment facilities and doctors in order to treat all severe injuries in a model manner, and the general practitioners will be sufficiently well-trained to handle the lesser ones themselves

Three facts logically lend momentum to this development, which must sooner or later take place, namely

1 The objective need for treatment facilities for those injured in accidents, based on the increase already present as well as the expected further increase in the number of accidents

2 The importance of the capacity to work and its best and most rapid restoration for the entire nation and its obligations

3 The real superiority of special treatment facilities for accident victims

When the aim of this development has been completely achieved by the establishment of an unbroken network of independent accident stations and accident hospitals, and all students and general practitioners have been well trained in the university clinics for accident surgery, the number of *avoidable treatment complications* will steadily decrease

Elimination of Inadequate Methods of Treatment

In the *treatment of wounds* a warning must be sounded against suture of the skin without meticulous excision of the wounds The wounds as a rule may only be sutured within the first 6 to 12 hours Purulent and infected wounds may not be closed by suture even with the use of antibiotics

The *uninterrupted immobilization* of all injured parts with simultaneous painless exercising of all uninvolved parts of the body may not be forgotten

In order not to disturb the rest required for healing, the wounds may not be tamponaded, irrigated with antiseptics or bathed

The less one disturbs the wounds after thorough initial treatment the shorter time is required for healing

Uninterrupted rest must not be confused with neglect of the wounds and of the wounded In the first days or as long as there is fever, the general

[1] In Austria some subjects are taught as subspecialties in which no examinations are given

condition of the patient must be checked at least twice daily and in the presence of rising temperature, the wound must be inspected to see whether infection is present With the exposed treatment of wounds one always has a good view of the wound area and does not need to disturb the rest by a dressing change

With every treatment method one must ask whether the rest that the wound needs to heal is not disturbed or interrupted by its use In respect to rest it must be emphasized that the "*uninterrupted*" is often forgotten in spite of the fact that it is the essential feature

As particular advantage of the uninterrupted immobilization, I wish to bring out that the patients even with extensively comminuted fractures and extensive soft tissue *injuries* are usually *completely free of pain* and usually are the picture of health, because infection is usually minimal and they lose a minimal amount of their fluids

Tendon Suture Severence of flexor tendons in the fingers or in the palm as a rule should not be primarily sutured, but rather repaired secondarily or replaced by graft.

Fracture Treatment In treatment by *fixation* all types of bandages that, as a rule, lead to disturbances of mobility in older people must be avoided To these belong all splints that hold the fingers extended (see example I, p 2163 and Vol I/fig 1339) or that immobilize the hand in volar flexion (Vol I/fig 1163) and the triangle of Mideldorpf (Vol I/fig 829) For the foot, all types of bandages that hold it in supination must be avoided (fig 2661)

One will not achieve a good result using *plaster casts* if one does not perform a satisfactory reduction before its application, if one pads it heavily so that the reduced fragments can redisplace or, if one removes it too soon (because redisplacement will occur) The result will also be bad in older people if they have not used the injured member during the necessary time of immobilization If one performs an adequate reduction and immobilizes long enough and has the patient exercise, good results will usually be achieved in suitable cases by plaster casts

When *traction* is utilized, the result will be unsatisfactory if one does not pull in the right direction, if one uses too little or too much weight or removes the traction too soon (see example 5, pp 2168—2172)

If one uses too much weight delayed callus formation or non-union occurs, for example at the tibia as well as all of the damages presented in Vol I/pages 26, 27 If one uses too little weight, angulation and shortening will result (see example 5, pp 2168—2172)

Massage and Passive Motion The use of massage and passive motion for *fresh* fractures and joint injuries is a common cause of poor healing and non-union This socalled functional treatment should therefore be discontinued altogether for *fresh* injuries Angulation, shortening and rotation cannot be avoided by massage, but *rather are magnified as long as the fracture has not* yet united The advocates of massage should, for example, answer whether they have ever been successful in achieving completely functional results after a

malleolar fracture with subluxation (see example 4, p 2167) This is impossible If, however, such an injury has been well reduced and has been immobilized long enough in a non-padded cast, that is until the fracture has united, and the patient walks conscientiously, he will later almost without exception walk normally Then they should answer whether they have ever achieved complete healing of a fractured navicular with complete restoration of function Treatment of this injury with massage will lead to non-union and permanent damage, while by uninterrupted immobilization for a suitable period of time this fracture will always unite with normal mobility and strength

Operative Treatment of Fractures Since one can exert suitable force with traction applied directly to the bone without damage to the soft tissues, it is thus almost always possible to achieve reduction even in markedly displaced fractures The operative treatment of *fresh* fractures, which in the hands of the inexperienced contains the hazard of infection, should therefore be limited by them to the most urgent cases, notably to fracture of the neck of the femur, the patella and the olecranon

Since with operative treatment many deaths and many protracted infections occurred, one should ask the advocates of operative treatment whether they have seen that otherwise healthy individuals, after a closed fracture, have died after withstanding the initial shock or have developed osteomyelitis Both are rare Without any treatment whatsoever a fracture can never heal as badly as those pictured in Vol I/figures 258—260, 1036—1038 and Vol II/figures 2091—2098 that were treated operatively In extra-articular nailing of femoral neck fractures and closed intramedullary nailing of femoral shaft fractures, the fracture site is not opened and therefore the danger of infection is small with suitable technique

Psychological Treatment One must not tell the patient that he will never be able to work again (example 7, p 2173 and example 8, p 2174) Also any comment to the patient that a previous treatment was not good must be avoided It is then all the more indicated to criticize and stamp out unsuitable methods in professional circles

Logical Follow-through of Treatment In the entire field of accident surgery it is not important that one have expensive apparatus and instruments but rather that one utilize only a single method of treatment in the individual case and follow through with it consistently doing everything at the correct time, in the right place and in the proper sequence The treatment of a fracture may not be carried out with the recipe Take a fracture, novocaine, plaster, gauze bandages, stainless steel wire, a Braun splint and mix them all together, but rather the when and the how are important The best reduction is of no value if the fragments are not held immobile uninterruptedly until they have united (see example 4, p 2167) The immobilization of a fractured member after good reduction can in an older individual produce more damage than the injury itself, if during the necessary period of immobilization all uninjured joints are not moved daily through their full range of motion (example 1, p 2163) Only thus can one achieve good function and at the same time maintain the patient sound of mind and body

V ORGANIZATION OF THE OPERATION OF THE OLD ACCIDENT HOSPITAL (VIENNA XX)

The hospital is in operation day and night, weekdays and Sundays Enough experienced doctors, surgical nurses, X ray nurses as well as the necessary lay personnel are available at all times

The severely injured are brought by the ambulance service from the factories and in traffic accidents from the road The slightly injured come by streetcar or in a company car

Shock Room When the patients are in shock, they are brought into the shock room where they are immediately warmed up and if necessary local anesthesia is administered At the same time blood pressure is taken and the pulse is counted Both findings are recorded at regular intervals on a separate sheet In the presence of low blood pressure the blood group is immediately determined and blood or plasma from the blood bank, or plasma substitutes are administered, if the blood pressure does not rise after local anesthesia and application of heat (see Vol I/pp 134—137) Further examinations such as roentgen examination, etc are deferred until the patient has recovered from shock When necessary an operation is performed

Measures for Recognition of the Injuries The indispensible prerequisite for suitable treatment and a subsequent just disability evaluation is an exact diagnosis of the injury This is only possible by a meticulous history and a conscientious examination of the patient by a doctor experienced in this field The correct conclusions can later only be drawn if the results of the examination are exactly recorded All findings of the history as well as of the examination and the treatment are therefore immediately recorded in writing and not after days or weeks Toward this end the management has generously placed sufficient stenographic help at the disposal of every doctor

Admission Room Every patient in whom an urgent operation is not necessary and who has no significant pain first comes to the reception room There all data of the patient are recorded by trained stenographers on forms that are similar to those of the reviewing surgeon system (see p 2229) namely first and last name, date of birth and place of birth, citizenship, address, activity at the time of accident, address of the plant, type of industry, his district health or accident insurance Then the story of the patient regarding the accident, namely date, hour and minute of accident, place and mode of accident, beginning of ambulatory treatment (again date, hour, minute) The exact times *reported* are especially important in traffic accidents If the patient is unconscious or irrational these dates and especially the mode of injury are obtained from the accompanying persons as far as possible

Waiting Room From admission the patients come into the waiting room

Examination Room The ambulatory patients are called into the examining room over the loudspeaker The severely injured are brought directly into the examining room by the ambulance service There two to three doctors who have had two to four and more years of experience in accident surgery, two to three nurses and two to three stenographers are on duty from 8 00 a m to 9 00 p m, and if necessary at night They examine every patient *avoiding*

pain as much as possible At this examination everything is measured, counted and weighed Some will object that one cannot thus grasp the heart of the problem However, during treatment and at the time of subsequent examinations, one has an exact *record* We gain the confidence of the patient, if we do not require them to wait long, examine them gently and relieve them quickly of pain First the height and weight are determined If one knows the age in addition, one can already have a good concept of the patient, while the frequently used expressions, for example, average sized, average development, can express varying characteristics Then the examination is conducted as accurately as possible The measurements and findings are dictated immediately into the typewriter in the metric system After a short report about the general condition of the patient, examination of pulse and reflexes follows Then the examination of the mobility of all joints on both sides for comparison Then the exact description of the site of injury follows, as well as of the loss of function Length and width of the wounds are measured in cm and their depth is estimated The estimation of the depth with the description of the injured tissues and organs is often not possible until operative treatment It is here also recorded in writing immediately Every doctor has his own stenographer Every workday we see on a average of 150 fresh injuries The highest number in one day was 315

The forms are filled out with two carbon copies The Accident Hospital keeps the original The first copy is sent to the General Accident Insurance Company and the second to the District Health Insurance Administration

In addition, at the same time, two forms are filled out for the hospital administration for billing and one each for the chart for the outpatient department and the outpatient card for the patient

X-ray Examination When a fracture or a dislocation has been diagnosed or there is a suspicion of such an injury or of a disease of bones and joints, the patient is immediately sent into the waiting room of the X-ray department where currently 11 X-ray technicians work In fresh injuries the site of injury is locally anesthetized before the roentgen examination, in order to free the patient of pain Thus he can be placed in such a position that exposures in both main planes are possible The site of injury must be indicated by the examining doctor with a red cross in order that the X-ray technician knows where she should direct the central ray She may not make a roentgenogram if the red cross is missing *In this manner it is possible not only to recognize* or to exclude fresh bone or joint injuries immediately, but also to register previous injuries and pre-existing diseases of the skeleton which is of great importance for disability evaluation Two hundred to three hundred roentgenograms are made daily The roentgen findings are immediately dictated The roentgen number is immediately recorded on the file Thus the roentgenograms can quickly be found during treatment and later at disability evaluation, whereas searching for films, especially for patients with common names, can become quite involved Mistaken identity involving films is thus almost impossible

Changes due to diseases not related to accident and sequelae of former injuries, especially in the area of the new injury are conscientiously noted, in order that they are not later implicated as sequelae of the new injury

Doubts concerning the origin (aggravation) from an accident (question of connection with the accident) are immediately answered positively or usually negatively When, for instance, a patient with an open fracture of his lower leg is brought in, which he has sustained during his work as the result of a fall from a scaffold it is very simple to dispel doubts concerning the origin of the injury or its connection with his work In questionable cases the question can only be answered with sufficient certainty, when one has adequate knowledge of the social legislation and the usual legal decisions In unclear cases one will express one s doubts (questions of connection with work, see pages 2249—2255)

Then it will be determined whether or not the individual is *capable of working* or not This is not only dependent on the type of injury, but also on the type of work If one has a sedentary occupation, he can often continue to work with a minor injury of his leg if the distance to his place of work is not too great Patients whose wounds have been excised and sutured are usually not allowed to return to work for several days with the exception of minor wounds on the head or in the face, because it has been our experience that otherwise wound complications occur

The estimation of the expected duration of treatment and expected inability to work requires considerable experience Often these can only be approximated Usually the duration of treatment and the duration of inability to work are the same There are however injuries with which the patient is able to work after a short time, while the treatment stretches out over many weeks or months Self-employed persons (doctors, merchants, etc) tend for instance to resume their full duties in a plaster cast 1 to 2 weeks after a severe fracture-dislocation of the ankle or a fractured vertebra However, the treatment requires 3 to 6 months (see Vol I/p 350, p 1928) This factor must also be considered with workers and employees with corresponding occupations *Individuals with injuries of the arms can, for instance, work in a supervisory capacity* Many workers are happy if their ability to work is restored by suitable bandages, because their wages are higher than their sick pay

Finally a report is made to the national health service stating the day that the Accident Insurance assumed the cost of treatment

If we work exactly and conscientiously at admission and at the initial examination and record everything immediately in writing, we can clarify most cases from a diagnostic standpoint as well as from a judicial standpoint The disability evaluation is then later quite simple and disputes about the relation to the accident and drawn-out law suits, which torment the injured patients and cause the insurance carriers unnecessary work and expense, occur only seldom We thus tend to maintain the *social peace* Still more important, however, is the fact that we arrive at a *clear diagnosis of the injury*, and this is the indispensible prerequisite of a purposeful and well-planned treatment

In severe injuries requiring admission to the Accident Hospital red forms are used instead of the green ones, in order that they may immediately be

recognized during further treatment and calculation of expense In addition a medical record is immediately started on which the history and the findings are especially exactly recorded Notations are also made in regard to the examination of the inner organs In injuries of the legs the presence of flat-feet or varicose veins it noted Diseases of the joints will be searched for in every patient The condition of the pulse is tested The reflexes are always tested in order that serious nervous system diseases are immediately discovered and that they are not later claimed as sequelae of the injury In older injuries that have healed with disturbances of function special emphasis is laid on a suitable history One must clearly understand from the history what circumstances of the former treatment have led to the present condition In the diagnosis the often used words Status Post f i femoral fracture should never be used, but rather it must be clearly expressed what this state was, for instance non union after femoral fracture, angulation with shortening, *extension stiffness of the knee joint after femoral fracture*, etc In the description the shortening must be given in cm and the range of motion of the joint in degrees

I will not, however, conceal the difficulty of convincing many doctors of the *importance of history-taking and of an exact examination and, thus, of* establishing a clearcut diagnosis, which is the prerequisite of every treatment It should not occur that anything is treated or preferably operated upon according to some hazy concept (autistic, undisciplined thinking according to *Bleuler*) without giving much thought to the consequences and the fate of the patient

Since most doctors don t like to write, and I count myself among these, we have enough stenographers and typewriters everywhere so that all findings can immediately be dictated When no stenographer is available at night or on Sunday after 5 00 p m , the findings are dictated into a dictaphone

After establishing the exact diagnosis, treatment is begun Small injuries are treated in the examination room and are sometimes immediately sent back to work

Alleviation of Pain In all painful injuries, whether open or closed, we alleviate pain as soon as possible by local anesthesia, and we avoid recurrence of pain after suitable treatment by the most exact immobilization with plaster casts (or otherwise), that are immediately split down to the last thread

Wound Excision All injured patients with fresh wounds are immediately taken to the operating room after the diagnosis is established There the wounds are excised and sutured if they are not older than 6 to 8 hours Wound excision is possible in most cases because, as a rule, the patients come for treatment within the first hour after injury Every day an average of 20 to 30 wound excisions are done These are followed by suitable immobilization with splints or plaster Often 2 to 4 doctors are kept busy with wound excision In 1955 we excised 8354 minor and also very major wounds Of these 97% healed without infection

Major Operations Injuries of the inner organs, for instance of the stomach the colon, the liver or spleen, the bladder or urethra, the lungs and the brain are immediately treated operatively as are all open fractures and dislocations

Some closed fractures are immediately reduced operatively Suitable femoral fractures are treated with the intramedullary nail Others are treated in traction In the presence of large skin defects pedicle grafts or free grafts are used In 1955 there were 382 such cases

Reduction of Fractures and Dislocations

The closed fractures and dislocations are usually reduced under local or, rarely, under general anesthesia in the cast room Every day as a rule 30 to 40 new casts are applied, in the case of fresh injuries, these are immediately split and suitably *inscribed* The roentgenogram is sketched on the cast so that the type of injury, the reduction and immobilization as well as the dates of the necessary X-ray checks and the date for removal of the cast can at any time be read from the notations on the cast Often 4 to 6 doctors are occupied in the cast room Individual stenographers to whom the findings can *immediately* be dictated are also available in the operating room and in the cast room

Avoidance of Compensation Neuroses By the immediate determination of the time and place and manner of accident, the otherwise difficult question of relation to the injury is usually quickly clarified The insured patients, who are given a copy of their statements and their diagnosis in writing in the form of their outpatient card, later only seldom consider changing their statements about the mode, location and time of the accident By these measures we feel we contribute much to the social peace Much painstaking work has thus been spared the officials of the Accident Insurance Company The result of these organizational measures is the exceedingly rare occurrence of accident neuroses

One gains the confidence of the patient from the beginning by gentle examination and the utilization of local anesthesia in all cases before difficult X-ray examinations and before all operations This confidence is increased if during the treatment, one inquires about their family, their work and their wages, and telephones their family and tells them how they can most quickly obtain their sick benefit payments They then realize that the purpose of the Accident Hospital is only to help them and not to take away their benefits

Working-up the Forms The next morning all forms (see p 2229) must be in the administrative office of the Accident Hospital by 7 30 a m (see p 2229) Every morning the number of unfinished records is reported to me There are usually only a few They must be completed by 8 00 a m Then they are checked, sorted and sent or distributed to the proper places Every form is immediately typed with six carbon copies Thus, not only is recopying avoided, but also the possible errors that could thereby result are avoided In the new Accident Hospital (Vienna XII) a Ditto machine is used for this purpose The first copy is sent to the patient s Accident Insurance Company, the second to the patient s District Health Insurance Thus these two agencies are notified of every injury in the quickest possible manner and can make their investigations without delay The third copy remains in the Accident Hospital and is first given to the X-ray department The fourth and fifth copies go to the ad-

ministrative department for billing The working-up of the forms is carried out in a very simple way that differs sharply from that usually employed The copies are identical The first through the third carry the additional words Start of Ambulatory Treatment' The sixth copy which is printed on thin cardboard is given to the patient to serve as Ambulatory Treatment Card He is required to bring it every time he comes for treatment This card contains all information up to the heading "Summary of Findings' Thus the diagnosis and the findings are given to the patient We have seen no disadvantages from this and have the advantage that at the next examination we know immediately about the diagnosis and course The back of the Ambulatory Treatment Card states "The dressings may never be changed by the patient *If bleeding, pain or fever occur the patient should come to the Accident Hospital at once, day or night*"

Patients, who have received hard bandages (plaster, etc), are particularly cautioned that beginning pain, numbness or swelling requires immediate check of the bandages without fail The Accident Hospital does not assume any responsibility for the severe complications that could result from failure to heed these directions

Every freshly injured patient must without fail present himself on the next day at 9 00 a m in the outpatient clinic including Sundays and holidays, if he was not given other instructions

The seventh copy is also of thin cardboard It serves as an outpatient record and is identical with the first copy except for the last paragraph, which is not included The dates of the visits by the Chief of Service and the progress notes, X-ray check and cast removal are entered on this copy On the reverse side are noted treatment, additional progress notes and roentgen findings In addition the outpatient record has another detachable sheet on which, besides the name of the patient, the beginning and end of the ambulatory treatment, the protocol number, year and X-ray number are recorded This sheet is given to the patient On the reverse side is the admonition to preserve it well and bring it along when he reports for complications, for re-examination, or for disability evaluation It is then easier to find the necessary papers later as medical record, outpatient record and roentgenograms

Reconstructive Surgery People whose bones have healed in angulation, with non unions, limitation of motion, unsatisfactory scars and other complications of injuries, and who come in large numbers, are operated upon in the aseptic operating room on the fourth floor In 1955 for instance, 65 bone grafts, 210 skin grafts and 172 pedicle grafts were carried out

Subsequent Treatment in the Hospital All severely injured persons are admitted to the hospital until they are again able to walk or are able to be transported without danger Some are placed in traction ond others in plaster and their injured limbs placed on frames Most wounds are treated exposed The greatest emphasis is placed on exercise All joints that are not included in the bandage are actively moved through their full range beginning on the first day In paralyses these movements must be carried out passively but gently without causing pain. An accurate clinical record is kept on all patients



INDUSTRIAL ACCIDENT HOSPITAL
of the GENERAL ACCIDENT INSURANCE CO

Director Prof Lorenz Böhler

VIENNA XX, WEBERGASSE 2—6, TEL A 47-5 25

Refer to Protocol No 21353/53

Schwarz/Mutz/Dr Henninger

Ambulatory

Patient Data:

X ray number 194 932

Last and first name	Rath Fritz Height 1 62 Weight 67 kg
Date of birth	10 3 1931 Place Schwechat Nationality Austrian
Marital state	Married
Address	Vienna 23, Zwolfaxing 128
Type of work at time of accident	Locksmith
Employer type of business	Cablework
Address	ARIADNE Vienna 11 Hauptstraße 501
Responsible district health insurance	Geb Krk Vienna 1,
Responsible accident insurance carrier	AUVA
Date of Accident, Hour Place	3 7 53 7 45 p m At work

How did the accident happen? (In the patient's own words) While hammering out a piece of steel the head of the hammer of a co worker came off the handle and struck the patient in the right hand Arrives with a first aid dressing in a company car

• **Beginning of ambulatory treatment** 3 7 53 at 8 30 p m to 9 45 p m

Diagnosis Fractura aperta metacarpal II dext

Further treatment
Reported sick

Treatment Local anesthesia excision suture dressing 200 000 u penicillin dorsal plaster splint finger splint for dig II T A T (Dr Henninger)

Short d s ription of findings Pain in the right mid hand Proximal over the second metacarpal a 1 cm long contused lacerated wound In the middle one third definite angulation with a dorsally open angle Index finger flexion to 5 cm between the pulp of the finger tip and the palm and flexion of the long and ring fingers to loosely touching the hand Long finger extension to within 1 cm of the plane of the dorsum of the hand Thumb and little finger freely mobile Wrist joint dorsal 20⁰ volar 40⁰ left dorsal and volar 50⁰ Pronation supination elbow and shoulder motion unrestricted Crepitation over the metacarpal Impaction pain from the index finger Pain on pressure in the mid third

Result of x ray examination (if done) Open fracture of the II metacarpal right, with displacement by the full width of the shaft toward volar

Abnormal conditions not related to the accident (simply ennumerate I e previous accidents 1951 Fracture of the left radius in typical location

Origin (aggravation) of these by industrial accident probable — questionable — unlikely

Probable duration of treatment 6—8 Weeks

End of ambulatory treatment

Dr Henninger
Doctor

The Administ tion of the Accide t Hospital

To this end a stenographer is available to every assistant surgeon in charge of a service

The medical care is provided by four assistants (chiefs of section) and 16 resident doctors Of these, all are on duty from 7 30 a m to 2 00 p m daily except Sunday and holidays and 6 remain on duty from 2 00 p m to 10 00 p m depending on the requirements of the admitting office, the initial *treatment service*, the outpatient service and the wards At night, currently, three doctors are on duty In addition there is a chief of section for the out patient service

On Mondays, Wednesdays and Fridays the operations begin at 7 30 a m Before the beginning of these the Oberarzt gives me a report of all night admissions and all important cases For every operation the medical record, roentgenograms and suitable skeletal parts must be ready After the operation the findings are immediately dictated

On Tuesday, Thursday and Saturday the Oberarzt first reports new admissions and all important cases Then the report of the administrative office is examined, which among other things contains those cases for whom the costs of care are not covered I feel that it is important also for all doctors to concern themselves with these administrative facts

Roentgen Conference On Tuesday, Thursday and Saturday at 7 30 a m the roentgen conference is held It lasts 2 to 3 hours All doctors who are not prevented from attending by an urgent operation or by duty on another service should take part Usually 5 to 10 guests are also present Thus all roentgenograms of the *previous two days are systematically reviewed* in such a way that all roentgenograms of every patient are shown, every time 50 to 70 cases with 300 to 500 films are reviewed All roentgenograms are inscribed in the manner indicated in Vol I/pp 90—92 A skeleton must always be available Every doctor must report the age occupation, appearance and condition of his patients, the mode of the accident and the treatment, and then must describe the roentgenograms Since for all fractures check roentgenograms are made at certain time intervals, all doctors are informed about the further course of ambulatory patients who are currently under treatment With the roentgenograms at hand, the treatment and the plan of operation is again discussed and, in addition, various actual questions, for instance, callus formation the influence of massage, the question of traumatic tuberculosis and osteomyelitis, the relation of arthritis deformans and injury, aggravation , questions of causal relation to injury, etc

Rounds In the first ten years I made rounds in all rooms Mondays, Wednesdays and Fridays, from 10 to 12 o clock and thus saw all 120 patients more or less thoroughly At present I only make rounds twice a week, usually Tuesday and Wednesday from 5 00 p m to 7 00 p m on one service of 35 beds, during which I examine every patient thoroughly and *study all* roentgenograms In this manner I see every patient every fourteen days I consider thorough rounds every two weeks better than a daily quick tour of all *rooms* Besides, I see all newly admitted, the recently operated and all the seriously ill patients every evening Every day all control roentgenograms of the in patients are shown to me

For the quick review regarding every patient the small blackboard at the head of the bed is filled out in the manner shown in figure 3090 In patients with leg injuries, whose *pedal* pulses are absent because of arteriosclerosis, this is indicated by a "P" written with red chalk and crossed out One then knows that one dare not allow these patients to get up too early or to discharge them, because otherwise even small wounds, especially over the anterior margin of the tibia, the medial surface of the tibia and the malleoli do not heal for a long time

The stool and urine findings, all drugs administered, dressing changes and interventions, in case of traction, the weights and measurements are recorded on the temperature graphs in addition to the temperature and the pulse

A check is made whether the date of injury, the reduction or wound treatment and the date of proposed removal of the cast is recorded on the cast in addition to the roentgenogram or the direction and size of the soft tissue wound as well as the name of the treating doctor

All new admissions must be completely undressed for rounds Even men with injuries of the trunk or of the legs must completely disrobe every time Only thus can one avoid overlooking important details and one learns to know and to analyze various gaits Patients with arm injuries must bare their upper body completely All blankets must be removed from bed patients with traction apparatus or on frames, for rounds

I myself ask every new patient his name, age, occupation mode of injury and complaints Not until then do I allow the Oberarzt or the ward doctor to present the findings of their examinations After I have obtained a general impression by a glance at the small blackboard, at the temperature curve, and at the undressed patient, and have paid especial attention to changes in form, color, and warmth, I require all patients with injuries of the arm or leg to move actively all joints of the injured extremity, beginning at the toes or fingers and ascending to the hip or shoulder as far as is possible without pain These movements require only 20 or 30 seconds and I am thus informed about all important facts Every patient always attempts first to show the mobility of the injured joint and one is thus only too easily deterred from looking at the others, and it happens not uncommonly that these other joints become stiff In this manner it cannot occur that pre-existing joint disturbances go unnoticed Then all roentgenograms are systematically reviewed and discussed

In the case of head injuries the patients are asked whether they were unconscious, and if so, how long and whether they vomited The cranial and the peripheral nerves, all joints as well as the pulse are examined In abdominal injuries abdominal rigidity, ability to empty bladder and bowels, as well as the pulse and the tongue are investigated In injuries of the pelvis the urethra is examined Most men will say that these things are self-evident, but nevertheless in studying many records one finds that these examinations have been omitted

In all injuries of the skull and of the peripheral nerves a neurologist is called, who immediately dictates his findings and re-examines the patient at

certain intervals When necessary other specialists are also called upon (oph thalmologists, otologists, internists and urologists)

During palpation I call every patient's attention to the fact, that I will cause him *no pain* and I stop immediately if he feels the slightest pain Thus

3. II. 57 AUVA P

Piringer Johann 58 J.

Fract. aperta cruris dext. 3. II. 57

2. Woche
Drain entf.: 4. II.
13. II. Rönt.

1 Drain
T. A. T. fract.
Penicillin 2 x tgl.

Markdraht
Vollhautlap.
O. S. Gipsv.
Nagelext. 3 kg
3. II

3090 a

FIG 3090 a—Blackboard for the head of the bed of a 58 year old white man without pulses in his feet who has sustained an open fracture of his lower leg At the upper left is the date of admission in the middle the agency responsible for the costs (AUVA General Accident Insurance Company) and in the upper right a red P which is crossed out as indication that the pulses in the foot are absent Below this is the name and age of the patient In the third line is the diagnosis and the day of injury In the lower left the week of treatment is indicated so that one doesn t change the bandage too early or too late Below this the day for removal of the drain namely the day after injury is indicated and in the last line the day of the last X ray check In the upper center it is recorded that a drain has been inserted so that it is not forgotten but rather is removed in time Below this one can see that he has had tetanus antiserum in fractional doses and in addition received penicillin twice a day In the lower right the initial treatment is recorded namely after exact wound excision the insertion of a medullary wire into the fragments then covering the skin defect with a full thickness graft the application of a full leg cast that has been windowed and split and traction exerted to a Steinmann pin with indication of the weight of 3 Kg
Thus one can *quickly acquaint ones self with everything of importance*

a cry of pain is rarely heard Most, even the severly injured, are happy and often spontaneously say that everything is well with them If someone complains of pain or pressure from a bandage it must immediately be investigated

Usually one finds a reason for the complaint As soon as one implies that an injured patient is a malingerer or goes so far as to call him one, his confidence in his doctor is lost He will no longer cooperate in his treatment, and everything depends on his cooperation *With forceful measures we will never be able to get a patient's cooperation* Without being aware of it, he must do everything of his own free will All injured patients are called by name Thus one establishes good psychological contact with the patient Most patients are informed about the type of their injury, since they can read their diagnosis on their small blackboard and can see their roentgenograms sketched on their casts We inform the patient of the possibility of a complete recovery, when the opportunity presents itself, by showing him a similar case that is completely healed and free of complaints To the others we say no word about the possibility of permanent damage Everyone is taught that he must care for himself and his own injured part, and we see that most of them carry out their exercises with enthusiasm (Vol I/figs 477—492)

With the patients with *injuries* of the *spine* we must always see to it that they do not carry out too many or too heavy exercises, since everyone wants to outdo the others in feats of strength and dexterity (Vol I/figs 447—492)

In my lectures I repeatedly emphasize that the *psychological treatment* in fractures and other injuries represents at least half of the treatment It is self evident that the nursing care must be consistent with these fundamentals Doctors and nurses are so trained, that they renew dressings and change the patient's position without producing pain Good food is very important and has always been provided by the administration The presence of the many visiting doctors at daily rounds should not be underestimated Every injured patient is happy to be presented as an interesting case and tries to do his best

Rounds, with review of all the significant medical records and of all the roentgenograms, and with control of all exercises for 35 patients, usually last two to three hours

Every other week my representative makes similarly thorough rounds

The two ward doctors, each of whom has 70 beds, make rounds in the morning for about two hours They then read the medical histories of all newly admitted patients These have been already written at the time of admission and are now checked for accuracy It is determined whether among other things, the presence or absence of pain has been noted, and whether the depth of the wound has been recorded On afternoons and Sundays the first to fourth assistant surgeon alternate duty and rounds After every round and every evening, first the new admissions are reported to me, and then all noteworthy cases, especially those with fever Then the operation schedule for the next day is discussed

I must be notified of every dislocation even the most minor I have thus been able to examine 1200 fresh dislocations in the course of the first fifteen years The reduction was usually carried out by the assistant surgeon on duty in my presence Besides this every open fracture and every extensive soft tissue wound *must be shown* to me I also tried to be present at the incision of every

certain intervals When necessary other specialists are also called upon (ophthalmologists, otologists, internists and urologists)

During palpation I call every patient s attention to the fact, that I will cause him *no pain* and I stop immediately if he feels the slightest pain Thus

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Fig 3090 a —Blackboard for the head of the bed of a 58 year old white man without pulses in his feet who has sustained an open fracture of his lower leg At the upper left is the date of admission in the middle the agency responsible for the costs (AUVA General Accident Insurance Company) and in the upper right a red P which is crossed out as indication *that the pulses in the foot are absent Below this is the name and age of the patient In the* third line is the diagnosis and the day of injury In the lower left the week of treatment is indicated so that one doesn t change the bandage too early or too late Below this the *day for removal of the drain namely the day after injury is indicated* and *in the last line* the day of the last X ray check In the upper center it is recorded that a drain has been inserted so that it is not forgotten but rather is removed in time Below this one can see that he has had tetanus antiserum in fractional doses and in addition received penicillin twice a day In the lower right the initial treatment is recorded namely after exact wound excision the insertion of a medullary wire into the fragments then covering the skin defect with a full thickness graft the application of a full leg cast that has been windowed and split and traction exerted to a Steinmann pin with indication of the weight of 3 Kg
Thus one can quickly acquaint one s self with everything of importance

a cry of pain is rarely heard Most even the severly injured, are happy and often spontaneously say that everything is well with them If someone complains of pain or pressure from a bandage it must immediately be investigated

Examination

16 Everyone attends to the protection of the injured person against cooling On admission the doctor on duty and during operations the anesthetist is responsible for this care

17 The name, age, occupation, address, employer, the agency responsible for the costs, etc , is recorded for every patient 'Pensioner' should never be written alone for occupation, but rather the former occupation and for children the occupation of the parents (p 2229)

18 In the history it must be indicated whether the patient was conscious or unconscious and, if unconscious, who gave the history, also where the patient is from and how he was brought in By ambulance, lying down, sitting, on foot, alone or accompanied by someone, etc In old cases the history must be dictated by the doctor (see p 2229)

19 Time (day, hour and minute), place and mode of injury should be given as accurately as possible, but briefly (see p 2229)

20 The exact time of the patient's arrival must be recorded (see p 2229)

21 Previous illnesses and particularly previous injuries must be noted (see p 2229)

22 In addition to the above facts in old injuries the previous treatment and after-care including place, type and duration are accurately described (plaster cast, traction, operation, massage and passive motion, etc), in case of former operations the name of the surgeon, duration of hospital treatment and duration of disability

23 In case of traction the weights used and the duration of treatment in traction must be indicated

24 The outpatient record, the medical record and the roentgenograms of every patient who has been treated in the Accident Hospital must be gotten out and read before the examination

25 In the case of patients who have been admitted for the second or third time it is indicated who has carried out the initial treatment and the further treatment (wound excision, incision, reduction) and of what further treatment consisted

26 At the end of the history, especially in the case of old maladies, it is noted why the patient comes (pain, difficulty walking, etc), in the case of inflammation the patient is asked whether his sleep was disturbed by the pain

27 It is noted on the chart whether or not the patient arrives at the hospital splinted or otherwise immobilized in the case of fractures and joint injuries

28 In the report of examination the age, height and weight are indicated

29 In the report of examination the general condition of the patient (shock, disturbances of consciousness, etc), the subjective complaints (*pain*, difficulty working or walking, etc), *form* and *color* of the injured part of the body and the gait in those who are able to walk are indicated

30 In every injured patient the pulse is examined on both sides for fullness, rhythm and rate, namely in patients with leg injuries on the dorsum of

spreading cellulitis and every finger infection This was easily possible because I live in the Accident Hospital

The organization of the hospital can most easily be understood from the following excerpt from the duty instruction

Excerpt from the Duty Instructions

General

1 No conversation, particularly noisy conversations should be carried on in the treatment or patient rooms

2 There should be no laughter in the treatment or patient rooms (Praesente aegroto taceant colloquia, effugiat risus, dum omnia dominat morbus)

3 There shall be no smoking in the treatment or patient rooms This is particularly important during the examination or treatment of a patient

4 On every written note the name and address belongs on the left upper corner and the date with day, month and year must be written on the right upper corner

5 All records regarding time, size, weight, mobility, etc must be made in the millimeter, gram, second system One should not write large or small, good or bad, much or little, etc

6 Everyone should carry a small calendar with him

7 Everyone should carry a ruler, a tape measure, a "Fix" ruler with protractor and a watch

8 Everyone should carry the abstract of the duty instructions with him

9 The working day begins promptly at 7 30 a m Everyone should first check on the second and then on the fourth floor whether he is assigned to perform an operation or to assist

10 If someone leaves his place of duty longer than five minutes, he must leave the telephone number where he can be reached on the blackboard next to the telephone in room 19 When he returns to his place of duty he should erase the number

11 In case of illness, this should be reported by telephone by 7 30 If the illness lasts longer than three days the notification should be made to the chief of the outpatient service in writing He refers it to the director

12 When someone takes vacation he should arrange for another to take his place a week before he leaves This should be cleared with the first assistant surgeon

13 Whoever takes vacation should report his departure and return to the director On his departure he reports who has taken over his duties

14 Exchanging duty is allowed but must first be reported to the assistant surgeon on duty and to the director

15 Applications to the general director s office or to other officials as well as promotions must be reported to the director

46 The doctor who has taken over a severely injured patient is responsible for seeing to it that the patient is quickly put to bed and that shock is treated by warmth and local anesthesia He also should accompany him to the X-ray department

47 If a fracture or a dislocation is demonstrated or if such an injury is suspected, suitable roentgenograms must be made in both major planes

48 In fresh injuries that are painful the injured area must be locally anesthetized before the roentgenograms are taken

49 A smear and culture must be taken at the time of initial examination in every case of fistula, markedly inflamed wound and of every abscess for the determination of penicillin and streptomycin sensitivity

50 If the bacteria are resistant to pencillin and streptomycin the tests are expanded to include Chloromycetin, Aureomycin Terramycin, Supronal, etc

51 All fresh fractures of the calcaneus must immediately be shown to the assistant surgeon on duty (indication, treatment measures)

52 Before every osteosynthesis of a fresh fracture either the chief or the assistant surgeon on duty must be notified

53 Cases for reconstruction surgery must be shown either to the chief or to the assistant surgeon on duty before the proposal of an operation is made to the patient

54 Before old cases are admitted for operation the skin of the entire body must be searched for foci of infection If the skin is not entirely uninvolved, the patient must return at a later date

55 The cases admitted for reconstructive surgery should be brought to the Saturday conference There the indication and the various procedures under consideration and their results should be discussed

56 All letters from doctors must be answered, especially in the case of patients admitted for hospitalization on admission as well as on discharge They should contain no proposals for treatment that a general practitioner cannot carry out They must be signed by an assistant surgeon

Photographs

57 Striking and rare fresh and old deformities should *immediately* be photographed (in questionable cases inquire) One may not wait until the classical changes in form have disappeared as the result of swelling and hemotoma

58 Striking and rare fresh deformities may not be corrected by reduction or operation until they have been photographed

59 In all old deformities one should inquire before operation whether they should be photographed

60 Final photographs should be made of all who have been photographed In order that they are not forgotten the words final photo are stamped on the medical record and the outpatient record

the foot and behind the medial malleolus In the other patients at the wrist

31 In every patient the knee jerk and the pupillary reflexes are tested

32 In the case of shock the blood pressure and pulse are taken Both are regularly controlled and recorded on a graph

33 In the case of injuries of the pelvis or abdomen, as well as in central paralyses or paraplegia the patient is requested to urinate If this is not possible, he is catheterized The urine is examined

34 In the examination of mobility all joints of both arms and both legs are examined either simultaneously or first on the sound side and then on the injured side beginning with the fingers or toes and extending to the shoulder or hip and recorded without omitting any joint

35 If the motion of a joint is limited, its range is measured and recorded in degrees together with the measurements of the other side for comparison

36 In the presence of visible muscle atrophy the circumference of the limb is measured and compared with the measurements of the opposite side

37 The examination must be conducted in such a manner that paralyses are not overlooked

38 In the presence of paralyses the active range of motion and the passive range of motion are recorded In addition sensation is tested

39 Every injury of the central and the peripheral nervous system is presented to the neurologist as soon as possible

40 When paralyses occur during treatment, they are noted on the blackboard at the head of the bed or in the outpatient record and are suitably underscored

41 In all fractures of the femur and in the case of old fractures, the length and circumference of the extremity is measured and compared with the uninjured leg The same thing is done on removal of the immobilizing bandage and on discharge

42 The findings on admission and the history must be dictated during the examination on the day of admission if secretaries are available, otherwise on the next day at 7 30 a m

43 The dictation of findings on admission must be exact and correct and at the same time as brief as possible Only that may be dictated which one has actually examined and seen The word "perfect" should never be used especially not in the final examination

44 The admission slip must be signed by the admitting doctor

45 In case of fractures of the pelvis, femur, lower leg and calcaneus, and of supracondylar fractures of the humerus as well as for all patients who are to be operated upon primarily, the doctor at the admission examination requests within 5 minutes the preparation of the following

a the bed (from the ward),

b local anesthesia,

c extension wire or pins,

d the transfer of the patient to the doctor who is to continue the treatment

It should not occur that freshly injured patients should wait hours because of neglect of these measures

72 The anesthetist must immediately notify the operator if the patient's condition becomes bad

78 The anesthetist must have everything ready before 7 30 a m so that he can begin the anesthesia promptly

79 Every dislocation is shown to the assistant surgeon on duty

80 In every dislocation it is noted on the outpatient record or in the medical record, whether there is simultaneous damage to the arteries, nerves or bones, with what method the reduction was carried out, whether with or without anesthesia, how many seconds or minutes the reduction required and how the mobility was after reduction This is especially important after dislocations of the shoulder

81 Every patient who receives a plaster cast is recorded in the green book which is located in the cast room (name, age, number of the outpatient record, diagnosis, type of treatment, date and name of the doctor)

82 Every intervention (cast change, operation, etc) is in the case of ambulatory patients immediately dictated into the outpatient record by the treating doctor

83 The roentgenogram before reduction must be sketched on the cast in natural size over the site of the injury In addition, the dates of the accident, of the reduction, of the application of the cast, of the next X-ray check the date of removal of the cast and of the duration of fixation in weeks as well as the name of the doctor must be written so that it can easily be read If a number of casts are applied, the date of each must be recorded If the patient is not to bear weight initially, the date of application of the walking iron must be noted When a patient has come from elsewhere, a sharp dividing line is made between the dates of the cast that has been applied alsewhere and those of the casts applied by us

84 Roentgen checks may only be requested when they are necessary and not for fractures in which experience has shown that they never displace as for example in the navicular of the hand

85 *Every cast and splint together with the roentgenograms must be shown to the assistant surgeon on duty or to another who is autorized to countersign the bandage The assistant surgeon must sign his name on the cast legibly as proof that he has examined the bandage and the roentgenograms*

86 In all fractures of the femur, after removal of the immobilizing bandage (traction or cast) and after testing the stability of the callus, the shortening should be measured This should be compared with the uninjured side

87 After removal of the immobilizing bandages (plaster, splints or traction and after testing the stability the range of motion of the limited joints must be measured and compared with the uninjured and immediately recorded in writing

88 The roentgen controls are carried out Tuesday, Thursday and Saturday mornings Only in the case of leg casts the roentgen controls are done on Friday

89 Cast removals are done on Monday, Wednesday and Friday mornings

X-ray

61 The doctor on duty in the radiology department is responsible for seeing to it that the patients do not have to wait too long To this end he uses a protocol in which the name, age, diagnosis, time of arrival and of departure of every patient is recorded

62 If roentgenograms are necessary, the injured area or that to which the central ray is to be directed is marked, namely with a red cross In difficult cases the size of the film should be indicated This protects against mis-diagnosis and saves material and time

63 In interesting and unusual cases especial care should be taken to obtain excellent roentgenograms When necessary these should be repeated

64 The X-ray reports should be short and yet contain the important points Ordinary reports should as a rule not occupy more than three lines

65 In fractures of the femur in traction and in the case of other severe fractures the marking of the fracture site and of the required size of the film must remain for the entire period of treatment

66 Bone and joint operations may only be undertaken when suitable roentgenograms are at hand

67 At operation for removal of loose bodies from a joint a new roentgenograms is made after the application of the tourniquet

68 At the end of bone and joint operations (this includes amputations) and after removal of radio-opaque objects and sequestra, roentgenograms must be made before the wound is closed and the cast is applied in order that one can demonstrate whether the bones are in good position or all foreign bodies and sequestra have been removed

69 Roentgenograms are made of every amputation stump and of every bone or joint operation before discharge from the hospital

70 When roentgen checks are necessary, these are all inscribed on the same side

Treatment

71 Before every operation the indication is recorded in the medical record

72 Before the reduction of a fracture or a dislocation one should check to see if everything is ready

73 The anesthetist must examine the heart and lungs and the urine before the anesthesia

74 Every anesthetist must check the anesthesia apparatus before the anesthesia and see to it that he leaves it in good working order and that everything has been refilled, i e, nitrous oxide, etc

75 The anesthetist is responsible for seeing to it that the patient has urinated, that he is properly fastened to the table and that he has no dental protheses in his mouth

76 The anestetist is responsible for protecting the patient against cooling during the operation

106 The assistant surgeon on duty begins afternoon rounds at 5 00 p m after he has reported on the activity in admissions and the initial treatment station
107 The ward doctors on duty accompany the assistant surgeons
108 All doctors who are not otherwise occupied take part in the morning and afternoon rounds
109 The assistant surgeon on duty checks to see whether all orders have been carried out, whether all bandages are in order, and that the medical records are satisfactorily kept
110 At afternoon rounds the assistant surgeon should undertake only urgent changes of positioning of traction, etc and discuss everything else with the ward doctors
111 All orders should be given exactly and with suitable time indication

Organization

112 Borrowed books must be shown to the librarian on the first Tuesday of the month
113 The librarian is to make a report about all outstanding books on the first Tuesday of the month
114 A doctor reports daily whether the current journals and the reports of the Saturday conferences are present in the doctors dining room, and whether the books, the fracture and dislocation protocols and the bones are present in the X-ray room, or who has borrowed them
115 A doctor reports daily about entries into the guest book
116 The assistant surgeon on duty reports at 9 00 p m regarding
 a The doctors who have taken part in the afternoon rounds
 b The number of casts applied, cast repairs and casts removed
 c The number of press injuries caused by hand or foot control
 d The number of dislocations, when, how and by whom they were reduced and further treated, how long the reduction required and whether bone-, nerve- or blood vessel injuries were involved
 e The number of new inpatients and outpatients divided into industrial and nonindustrial accidents, the number of ambulance calls, letters from doctors and the incomplete medical records
 f Diagnosis, findings and treatment of all hospital admissions
 g In all femoral, lower leg and calcaneus injuries as well as of other serious injuries, how long the treatment took from the time of arrival at the hospital to the time of arrival in the patient room, what was done and who carried out the treatment
 h Condition of all new patients as well as of all earlier admissions worthy of note
117 The operation schedule should be made out by 9 30 p m at the latest so that the nurses can get everything ready
118 Only the ward doctors should be scheduled for surgery and not those who are assigned to the outpatient department, the initial examination department, the radiology department or the initial treatment department
119 The first assistant surgeon reports at 7 30 a m whether all doctors are present or who is absent and who has reported sick

Ward Duty

90 The ward doctors begin with rounds at 10 00 a m on Tuesdays, Thursdays, Saturdays, and Sundays and at 11 00 a m at the latest on Mondays, Wednesdays and Fridays If there is any delay the cause must be immediately reported

91 A younger doctor and the stenographer accompany the ward doctor to carry out his orders immediately in so far as possible

92 During rounds *both* arms or legs are always uncovered so that in addition to circulation, the mobility and the satisfactory position of the dressings as well as the inscription of the bandages can be checked

93 Every point of entry or exit of a pin is inspected so that signs of inflammation are discovered in time and severe infections and amputations are thus rarely encountered

94 During rounds all joints of *both* arms or legs are exercised

95 In all fresh injuries the mobility of the joints not included in the immobilizing bandages must be recorded on the temperature graph, in the medical record and later on the outpatient record

96 If the pedal pulses are absent a red P which is crossed out must be recorded on the small blackboard at the head of the bed (see p 2232)

97 The ward doctor must order the breath holding test, blood pressure determination and the determination of the blood group before major operations He should also check to see whether the necessary blood is available for transfusion

98 In all old injuries the range of motion of the involved joint must be recorded on the graphic chart on the day of admission and then every week in order to have a measure of the improvement

99 A short summary should be written in the medical record at the time of discharge An abstract of the neurological report should also be made

100 In injuries that require a series of operations a short plan of treatment should be entered in the medical record If another operation is still anticipated at the time of discharge, the type and proposed time of operation should be recorded in the discharge summary

101 The ward doctors report daily what time they began rounds what occurred, whether the medical records are in order and whether the pain and the depth of the wounds is recorded

102 The ward doctors report every Thursday whether they have made the so-called "blackboard rounds and have checked the medical records and the roentgenograms

103 The ward doctors report every Saturday about the transfers and about the condition of these patients after telephone inquiry

104 The ward doctors report every Saturday about the thromboses and emboli that have occurred during the week

105 Every Tuesday, Thursday and Saturday the card file book[1] must be gone over with the Oberarzt after the X-ray conference

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1 This card file book resembles a photograph album Every page has six compartments 5×15 cm and holds a card for each patient according to room number This card contains all the information contained on the small blackboard (fig 3090 a)

Further Treatment in the Outpatient Department

All patients who are able to walk, i e, most of those with wounds or closed fractures and dislocations in the region of the arms, can go home after treatment and are requested to return to the outpatient department on the next day The patients discharged from the hospital also return to the outpatient department The ambulatory patients are seen daily or at longer intervals according to need Every day between 400 and 600 ambulatory patients are seen in the outpatient department

Room Arrangement and Equipment The outpatient department consists of five treatment rooms, two administrative rooms, a large gymnasium for group gymnastics, a smaller one for individual gymnastics, a large waiting room for 200 to 300 persons and a cloak room The equipment consists of 20 heat cradles, two short wave apparatus, a diathermy apparatus, an electrodiagnostic electrotherapeutic set in addition to vertical and horizontal pulley exercisers with sandbags, flying rings, four wooden ladders for Swedish gymnastics, four finger ladders, exercise benches, knee-bending apparatus (Vol I/fig 124, Vol II/figs 1574, 1575), mountain climbing apparatus (Vol I/figs 21 22), medicine balls, rubber balls, spring dumb bells, exercise clubs staves, boards with screws for finger exercises Nothing is provided for massage Zander apparatus are not available

Personnel The outpatient department is under a permanent chief of service (Oberarzt), who takes part in the daily conferences of the hospital doctors and is in closest contact with the hospital, the initial examination department and the radiology department An assistant surgeon and three resident physicians are assigned to him These are assigned for nine months The working hours here are from 8 30 a m to 2 00 p m In addition the outpatient department has four gymnastic therapists and three nurses The all encompassing paperwork (keeping the protocols and the records, notification of the accident insurance companies, answering various inquiries, distribution of the transportation certificates, etc) is done by an administrative assistant and six stenographers Their working hours are from 7 30 a m to 3 00 p m

Treatment The outpatient department has three large divisions the so-called wound treatment area, the heat treatment area (heat cradles, short wave, diathermy) and gymnastics All patients present their outpatient card on arrival They are then called into the proper room by the loudspeaker system All patients with bandages come for treatment when the bandages are checked for satisfactory fit In the presence of complaints of pressure or pain the bandage is corrected If there is no complaint, the bandage is first opened on the day designated by the inscription Since 96 to 98% of the wounds heal without incident few dressings are necessary At the time of checking the bandages and the wounds all joints that are not included in the bandages are moved actively through their complete range of motion If limitation of motion is present, the patient is sent for individual gymnastics Patients with casts come in only once a week if they live far away Otherwise they come every other day for gymnastics The work in the wound treatment area is done by three doctors A stenographer is assigned to each She

120 The assistant surgeon on duty repeats his report from the previous evening at 7 30 a m and adds the number of free beds He repeats the surgical schedule on surgery days On Saturdays the report is made at 7 15 a m
121 Deaths are reported immediately during the day and those occurring at night by 7 30 a m at the latest
122 The assistant surgeon on duty reports at 2 00 p m how far along the treatment of the freshly injured has progressed, how many patients are still awaiting completion of their treatment and whether the telephone numbers of the assistants on duty are listed in room 19
123 The assistant surgeon on duty reports at 5 00 p m about the progress of the work in the initial treatment room, about the number of patients admitted to the hospital and of outpatients and the condition of the medical records and begins rounds with the ward doctor
124 One assistant marks the roentgen protocol every week and reports on Saturday morning how much of it has been transferred to the fracture and dislocation protocols
125 The first Assistant has an experienced doctor check the fracture and dislocation protocols every week to control whether operations (osteosyntheses, operative reductions, dislocations, removal of femoral neck nails and intramedullary nails, etc) have been entered and suitably marked, preferably in red pencil
126 He gives the protocol for reconstructive surgery, osteosyntheses, meniscus operations, nucleus pulposus hernias, etc to another experienced doctor
127 Every Saturday morning the first assistant reports whether all protocols are in order
128 He sees to it that the wound infection lists are finished by the 20th of the month at the latest
129 One experienced doctor is assigned to the radiology department, two experienced doctors to the initial examination department, three experienced doctors to the outpatient department As a rule these doctors should continue in the assignments for nine months
130 One assistant surgeon has the supervision of the cast room and the operating rooms for 3 to 6 months He demonstrates to the younger doctors the technique of wound excision, the reduction of fractures and dislocations and the proper application of casts He distributes and supervises the work there He countersigns all casts and splints Before doing this he examines the roentgenograms of the case in order to decide whether immobilization is necessary and whether the inscription is correct During this time he is not assigned to operations
131 The assistant surgeon on duty sees to it that no inexperienced doctors treat without supervision severe injuries for which they are not qualified
132 The assistant surgeon on duty sees to it that the work is kept flowing smoothly and that waiting periods are as short as possible

Such duty instructions can only serve their purpose if one checks daily or weekly to see that they are carried out, otherwise the various single requirements are soon forgotten

tinued There is no purpose in continuing treatment for months in cases in which no improvement can be obtained

Persons with injuries after which disturbances of mobility commonly appear are asked to appear daily for their exercises, for instance women over 40 with fractures of the radius The disturbances in mobility of the fingers and of the shoulder joint, that are so common with inadequate supervision after just this injury, can always be avoided by daily planned painless exercise

The Oberarzt supervises the entire operation and intervenes wherever he can lend guidance He also maintains liaison with the Accident Insurance Company, the state health insurance and the authorities An individual stenographer is available to him as well as to the Assistant Surgeon and each of the resident doctors

The assistant surgeon checks all patients with arm casts every Tuesday and those with leg casts every Friday to see that the bandages are still in order and that the inscriptions and the sketches of the roentgenograms are correct Every time 70 to 80 patients come On the other days he checks those patients who have been under ambulatory treatment more than eight weeks

A list is kept of all patients who have been under treatment more than eight weeks I formerly saw these patients every Wednesday Since their number has markedly increased in the last years the chief of the outpatient service examines a part of them every Wednesday It is then determined whether only unavoidable sequelae to the accident are present or whether avoidable treatment complications influence the duration of treatment The underlying mistakes are repeatedly discussed in order to avoid them more and more in the future Cases without hope of further improvement are then written off

All wound complications and tissue inflammations must be presented to the medical director or his representative

We seldom see *accident neuroses* We attribute this to the fact that we endeavor to relieve the pain for the patient from the first instant of treatment by local anesthesia and then by meticulous immobilization of the injured parts During the ensuing treatment also, pain is avoided in so far as is possible Then we tell every patient what his situation is and about how long his treatment will require if we are not dealing with hopeless cases

If, for instance, a man with a moderately severe malleolar fracture comes with severe pain and we immediately render him pain-free with an injection and reduce his fracture and tell him that he will walk again after five or six days and that he will again be able to work in three to four months and will have no residuals whatsoever after a half-year to a year, and when that, which we have told him in regard to pain comes to pass and he is also assured of it by the other patients, then he will not get himself into the frame of mind that he must receive a lifelong pension

It is altogether different when we do not get a patient until later for aftercare If he has had severe complications, for instance shortening or angulation, one will not be able to correct this by massage In the after-treatment centers it was often customary to treat these people according to a definite schedule four to six weeks, for instance ten times external heat, ten times

enters the most important findings in the outpatient record and at the end of treatment the final report Thus we are in the position to inform ourselves about the course and result of our treatment for every patient The day on which the patient is to return is marked on his outpatient card and his outpatient record in order that next time one can see whether or not the patient has kept his appointment The outpatient record is so arranged that one can see if a patient has not appeared for more than 12 days

All patients with closed injuries with healed wounds or with casts come for gymnastics They are divided into various groups, namely, injuries of the trunk, fractures of the vertebrae, foot-, lower leg-, knee joint- and femoral fractures, shoulder and upper arm injuries, elbow and forearm injuries, and *finger injuries Every group exercises 30 to 40 minutes All joints of the entire* body are exercised During the exercise everything is avoided that can produce pain In order to protect the patients from the energetic passive movements by too ambitious "helpers" a placard is displayed on each of the four walls of the two gymnasiums which states

No Exercise May Cause Pain

Many believe that one thus undermines discipline and gives the fainthearted an opportunity to avoid effective treatment I can however de*termine that just the opposite is the case We can repeatedly show our guests* that the patients carry out the exercises with pleasure, because they never have to fear pain and because they can see results They do not regard us as persecutors but rather as helpers I reject all exercises in which the patients groan and cry with pain and the masseurs and the massaged sweat from exertion We are especially careful with the movement in recently injured patients and in reduced joints We therefore seldom see swellings that are not direct consequences of the injury For the same reason myositis ossificans after elbow and hip dislocations is almost unknown to us (see Vol I/pp 48—50, 60—76) In the large gymnasium the chief aim is to increase strength and endurance The mobility then makes rapid progress if the joint has not been damaged

Those patients who have resistant limitation of motion come to individual exercises There every joint that is limited is exercised *avoiding pain* The joints are usually warmed but not overheated beforehand In order to avoid overheating a placard with the inscription *heat treatment may not last more than 15 minutes* is displayed on every wall of the heat treatment room When the joints are overheated, vascular disturbances appear The skin becomes marbled a blue-white The blue streaks are thromboses Between them lie the white bloodless areas Later the blue areas become brown If one makes roentgenograms one sees a spotty bone atrophy under this skin The joints become painful from overheating alone and the mobility decreases The condition becomes aggravated if the joints are vigorously massaged and energetically passively moved as is recommended The doctor in charge of gymnastics supervises the exercises and dictates a short note about the mobility of the joints in degrees A stenographer is available to him for this If he sees that the mobility does not increase the treatment is changed or discon-

Room Arrangement In the castle are 60 beds, a roentgen station the gymnasiums, a dining room with kitchen, living rooms and work rooms and, in an adjacent building, 30 beds and a living room Every patient has his own place at the table in addition to his bed in the patient room, and in addition another in the reading room or in the living rooms Furthermore there are 20 work places in the work rooms so that 290 places are available for the 90 patients

Personnel consists of 2 doctors, 1 administrator, 2 gymnastic instructresses, 1 occupational therapist, 1 work director, 4 administrative employees, 6 nurses, 8 kitchen helpers, 11 attendants, 2 stationary firemen, 2 gardeners and 1 doorkeeper

In this institution the further treatment of the severely injured is carried out In addition there are also usually 30 freshly injured bed patients or patients who have had reconstructive surgery that have been transferred from the Accident Hospital when there is a shortage of beds Disturbances in mobility of joints and muscular weakness are improved or cured by *painless* exercise Amputees are prepared for the wearing of prostheses and later instructed in their use Patients with paralyses are taught to walk with orthopedic appliances

Gymnasiums, and in summer a meadow and a swimming pool are available for exercise The patients can obtain recreation on the sun decks and in the bowling alley Besides, bowling is a particularly good exercise because all joints of the body are vigorously moved

The muscles are strenghtened by the exercise, the limbs regain their mobility and dexterity Also here, as in the Accident Hospital, every wall of the exercise rooms displays a placard with the following inscription

No Exercise May Cause Pain

There are no provisions for hydrotherapy such as hall and steam baths, underwater massage, etc, because in all such institutions I have observed a striking number of swellings, cyanosis, and disturbances of mobility This was first emphasized to me when, in 1917, I was assigned a physiotherapist who had been trained in Sweden She was full of enthusiasm I had to equip two rooms with 20 beds for her There she set up large bathtubs and small ones for hand and foot baths, in addition massage tables and Zander apparatus (for passive movement) While I had previously seen no significant swellings or cyanoses in my gunshot fractures and joint injuries after suitable wound treatment, reduction and uninterrupted immobilization with *painless* active exercise, these occurred in most of those treated with hydrotherapy and in many cases the mobility of the fingers became worse In some of the fractures of the femur shown on page 2260 (figs 3094—3096) swelling of the knee and ankle joints occurred and the lower leg and foot of the injured side became cyanotic These occurrences disappeared as soon as the patients were no longer sent for this treatment In 1956 [1] at the German Chirurgenkongreß I described

[1] Bohler L Ist das Sudeck Syndrom nach geschlossenen Verletzungen eine unabwendbare Unfallfolge oder eine vermeidbare Behandlungsfolge? Langenbecks Archiv u Deutsche Ztschr f Chir *284* 43 1956

diathermy, ten times massage, etc, and afterwards, since the treatment should have a good result, to reduce their disability payments by 10 to 20% This was unjust because shortenings and angulations cannot be improved by these measures After the reduction in disability payment these persons have said not without reason that they have been unjustly treated They went from one court to another and from the repeated examinations became accident neurotics

That every injured person only thinks of his disability settlement from the beginning is, according to our experience, entirely untrue On the contrary, we repeatedly hear that the freshly injured persons say, "What should now become of me, if I no longer can work? And we have won their confidence if we can tell them that they will soon be able to work again If an injured person on the other hand must undergo a painful treatment, he will soon concern himself with thoughts of compensation

This most common cause of accident neurosis must be repeatedly emphasized because some accident insurance carriers unfortunately still regard *massage* and *passive* motion as the basic pillars of accident treatment procedure They repeatedly ask whether the patient is being massaged or is undergoing passive motion and by whom this is being carried out They still don t appear to know that in the case of many injured persons healing is thereby delayed and in some it is prevented (see Vol I/pp 48—50, 60—76) and that one not only damages the body of the patient but also his spirit

Cooperation between the Doctors, Nurses and Administration

The work can only be carried on without friction, when everyone works together and when every group brings understanding and trust to the next and the control measures are so carried out that the work is facilitated and not hindered The filling out of the admission forms, the medical records, the protocols, the answering of various inquiries, etc, that are so important to the diagnosis of the condition and for a logical productive treatment, can only be carried out when the doctors are supported by the administration How this is done is shown in the organization table that has been developed by the administrator, Puhringer Unfortunately this has in the meantime been changed

Consultants Three neurologists are available for the examination of brain-, spinal cord- and nerve injuries They examine every injury of the central or peripheral nervous system either on the day of the injury or on the next day and then serially as required These exact reports made immediately after the injury contribute much to the avoidance of pension neuroses

In addition the Accident Hospital has a consultant in internal medicine, in urology and in eye injuries

Rehabilitation Center Stollhof

In 1939 the so called castle Stollhof which had been built in 1909 in Klosterneuburg Kierling was purchased, together with its 70,000 square meter park It is located 13 Km from the Accident Hospital

training possibilty with systematic visits to the rehabilitation center has become impossible for most

The costs of patient care for one day are S 59 68 (DM 10 —, U S $ 2 30)

VI DISABILITY EVALUATION

After the conclusion of the treatment an estimate of disability as a result of the accident is made Of patients treated in the Accident Hospital 93 58% healed without reduction in their capacity to work, 3 6% with temporary disability and the remaining 3% with permanent disability These include especially those with amputations or paralyses

All patients with temporary or permanent reduction of their capacity to work are examined by doctors of the Accident Hospital who are especially experienced in this field To this end all records and roentgenograms from the day of the accident to the close of treatment are available for all those patients treated in the Accident Hospital This simplifies a just estimate of the disability very much

The fact that the number of appeals to the courts against the awards made by the institution continue to be fewer, shows that it has been possible to arrive at just estimates Formerly the patients were evaluated only by doctors who had not taken part in the treatment However it has proved desirable that the doctors carrying out the treatment also evaluate the disability, because the course of the treatment is known to them, and because it is valuable for their experience to be able to follow the sequelae of injuries for years or decades

Every year about 4,000 disability evaluations are made Dr Mayr [1] in his book has presented the methods used by us in disability evaluation

Questions About Relationship to Injury

Before the introduction of accident insurance many morbid conditions have been attributed to the influence of injuries We now know that they result from congenital or constitutional factors or from infection Legislation in regard to accidents has here given a big stimulus to exhaustive research regarding these conditions, the effect of injuries on them and the effect of the injuries on physical and emotional productive capacity, as have never before been required of medicine to such a degree The problem of the relation of tuberculosis to the injury which was formerly very vague pressed for solution Similarly the question of the origin of traumatic osteomyelitis and other urgent questions required an answer The research about meniscus injuries and meniscus damage is still fluid The industrial diseases by virtue of their being included by the accident insurance carriers as compensable conditions were also made objects of the most eager research

Moreover, the practices of the accident insurance carrier have led to particular attention of the medical profession to accidental injuries The accident insurance carrier required roentgenograms in both main planes in

[1] Mayr S Praxis der Begutachtung Wien Verlag Maudrich 1954

the origin of Sudeck's syndrome as the "steam saturated underworld" Many doctors and laymen do not seem to know that the old strength and mobility returns by itself after most closed fractures and many open fractures and joint injuries, if one performs a good reduction, carries out uninterrupted immobilization until union has occurred and actively exercises In young patients exercise is not even necessary If patients get well in spite of intensive application of heat as well as massage and passive motion, they believe they got well because of them We only send 1 to 2% of our patients to the rehabilitation center I avoid intensive hydrotherapy because I have the impression that more harm than good results from its use Where the facilities are available, they are usually used and often too early and too intensively In the later stages of an injury hydrotherapy is sometimes useful It is especially valuable in poliomyelitis Besides, in visiting the very well-known rehabilitation center of Henry Kessler in Newark (near New York) I noted that he also uses no hydrotherapy According to my estimate, intensive hydrotherapy is useful for 10% of all injured patients, for 40% it is indifferent and for 50% harmful It seems to me important that individual rehabilitation centers without hydrotherapy exist so that the doctors can see how it is also possible in the smaller hospitals and in practice to achieve good results with the simplest measures

But we have a *workshop* for wood and metal work under a director in which the patients can return to their former occupation or be retrained for new work The General Accident Insurance Company does not only make the workshop and the tools available to the patient, but also pays a part of the cost of the material There everyone can make useful objects that remain his property This fosters pleasure in work and the will to work

An occupational therapist shows the bed patients especially, but also those able to walk various hobbies and handicrafts Particular emphasis is placed on making useful items I[1] had already in 1917 in my hospital for gunshot fractures and joint injuries seen to it that no useless trifles were made

The patients are weighed on admission and on discharge Most of them gain significantly in weight

Detailed medical records are kept, the range of motion of the joints is measured with a goniometer weekly so that the progress can continually be followed and those that make no more progress can be discharged at the proper time

The patients are cared for by two doctors, and two physical education teachers carry out the exercise therapy Every Saturday the director of the Accident Hospital makes grand rounds in which formerly 4 to 6 doctors from the Accident Hospital participated They thus had the opportunity to follow in severely injured patients the progress of healing and the results of a *painless* exercise program, that can be carried out in every hospital and to a great extent also in private practice with *the least expense* As a result of an interpretation of the doctors new work rights that are in effect since 1956 this

[1] Bohler L Wie schutzen wir die Verwundeten vor Amputation und Kruppeltum? Ztschr Orthop Chir *45* 268 1924

training possibility with systematic visits to the rehabilitation center has become impossible for most

The costs of patient care for one day are S 59 68 (DM 10 –, U S $ 2 30)

VI DISABILITY EVALUATION

After the conclusion of the treatment an estimate of disability as a result of the accident is made Of patients treated in the Accident Hospital 93 58% healed without reduction in their capacity to work, 3 6% with temporary disability and the remaining 3% with permanent disability These include especially those with amputations or paralyses

All patients with temporary or permanent reduction of their capacity to work are examined by doctors of the Accident Hospital who are especially experienced in this field To this end all records and roentgenograms from the day of the accident to the close of treatment are available for all those patients treated in the Accident Hospital This simplifies a just estimate of the disability very much

The fact that the number of appeals to the courts against the awards made by the institution continue to be fewer, shows that it has been possible to arrive at just estimates Formerly the patients were evaluated only by doctors who had not taken part in the treatment However it has proved desirable that the doctors carrying out the treatment also evaluate the disability, because the course of the treatment is known to them, and because it is valuable for their experience to be able to follow the sequelae of injuries for years or decades

Every year about 4,000 disability evaluations are made Dr Mayr[1] in his book has presented the methods used by us in disability evaluation

Questions About Relationship to Injury

Before the introduction of accident insurance many morbid conditions have been attributed to the influence of injuries We now know that they result from congenital or constitutional factors or from infection Legislation in regard to accidents has here given a big stimulus to exhaustive research regarding these conditions, the effect of injuries on them and the effect of the injuries on physical and emotional productive capacity, as have never before been required of medicine to such a degree The problem of the relation of tuberculosis to the injury which was formerly very vague pressed for solution Similarly the question of the origin of traumatic osteomyelitis and other urgent questions required an answer The research about meniscus injuries and meniscus damage is still fluid The industrial diseases by virtue of their being included by the accident insurance carriers as compensable conditions were also made objects of the most eager research

Moreover, the practices of the accident insurance carrier have led to particular attention of the medical profession to accidental injuries The accident insurance carrier required roentgenograms in both main planes in

[1] Mayr S Praxis der Begutachtung Wien Verlag Maudrich 1954

every fracture as well as in every suspicion of bone or joint disease including films before and after reduction as well as during treatment They spared no costs to exhaust all possibilities available to the doctor Many advances in the field of the treatment of fractures and dislocations were thus first made possible Diseases of the joints that were already present before the accident are discovered in this way and later controversies about relation of disease to injury, which torment the patient and cause the insurance carrier unnecessary work and expense, are avoided

As a result of this research we now know that inguinal hernias, varicose ulcers, osteomyelitis, bone and joint tuberculosis, bone tumors and most internal and neurological disorders are as a rule not related to an injury and that one must therefore in answering the question of relation to an injury express one s doubts if one cannot prove the relation in the form required by the law

In the application of the above mentioned diagnoses one must be particularly careful not to designate an unquestionable contusion of the back as lumbago or a purulent ostitis as osteomyelitis, because this may lead to long drawn out controversy concerning the relation to the injury

Hernias usually originate from a congenital predisposition and are therefore generally not recognized as sequelae to injuries Exceptions are those hernias that result from a direct injury of the abdominal muscles or that develop in the scar of an abdominal injury, if this injury is accepted as an industrial accident In addition, the incarceration of a hernia during work is recognized as an industrial accident

The varicose ulcer of the lower leg as a rule is a sequel to poorly nourished skin of the lower leg resulting from varicose vein formation without external cause If an injury occurs to a varicose leg, disability payments are only made until the wound or the resulting ulcer has healed If a patient with a normal skin incurs a large wound of the lower leg with loss of skin, an ulcer commonly develops, especially after open fractures of the lower leg One should not designate this as lower leg ulcer but should always add "produced by injury" because otherwise the compensation will be disallowed

Osteomyelitis is an acute infectious disease of the growing years It develops suddenly like acute appendicitis or pneumonia and occurs most often at the upper end of tibia However, any bone can be involved There often is a history that on the previous day the patient bumped himself while jumping or that he fell or the like Now the question arises what healthy boy does not incur some minor injury every day? If he does not, he just isn t healthy As a rule such minor injuries have no etiological connection with the development of osteomyelitis Up to now I have not seen osteomyelitis follow a closed injury among the 750,000 injured patients of the Accident Hospital In order to demonstrate a relationship between this illness and an injury certain definite premises must be fulfilled, namely 1 The accident must be proved without a doubt 2 It must have been a considerable accident that can be demonstrated to have involved the later diseased area 3 The illness must follow the injury directly or at least within a few days As proof of a considerable accident evidence of trauma such as abrasion of the skin, or ecchymosis, at least in the form of a black and blue mark must be demonstrable

Osteomyelitis can flare up after years or decades At the time of recurrence therefore the action of a considerable force must be proved in order to recognize an 'industrial accident" A sharp distinction exists between acute osteomyelitis and *traumatic ostitis* If as a result of the action of considerable force, i e, by being run over or by a gunshot, an open fracture occurs, inflammation of the fracture site commonly develops The bone marrow is usually involved only for a distance of 5 to 10 mm Therefore a large marrow sequestrum and an involucrum does not develop, but rather only the casting off of splinters and ring sequestra This inflammation is without question the result of an injury Since most insurance adjustors at the trade associations are conditioned to disallow osteomyelitis as a rule, they often also stop compensation in the case of true traumatic ostitis, if a doctor has used the word osteomyelitis in a report It them sometimes requires a protracted procedure before the patient receives his just compensation Ehalt[1] has published two cases from our large material in reference to this problem

Bone and joint tuberculosis were also formerly considered sequelae to injuries In reality it is always the result of metastasis of tuberculous organisms from a focus in the lungs or lymph nodes A traumatic origin is exceedingly rare For it to be recognized as related to injury the following conditions would have to be fulfilled 1 The accident must be proved without a doubt 2 The accident must have caused a considerable injury at that area of the body where the disease later develops 3 There must be a time relationship between the injury and the first sign of disease which can be brought into line with the known time required for the development of the disease The manifestations of the tuberculosis may as a rule not appear before four weeks and not after six months One usually finds that the report of accident has been submitted late and that the history is very vague Sometimes one finds that the involved joint was already diseased long before the accident

Already existing bone and joint tuberculosis can be significantly aggravated by injury But also in this case the accident must be completely documented and must have been severe in order to be recognized as causative I have seen only one case of bone tuberculosis that has developed as the result of an injury in all of our 750,000 injured patients

One of the commonest disabilities that is often attributed to an accident is *Lumbago* It usually occurs while lifting insignificant burdens, for instance, a helper throwing bricks to the mason, namely in an activity common in the building industry, sometimes even in straigthening up from a stooped position The commonest cause of acute lumbago is the prolapse of a nucleus pulposus Since the lumbago almost without exception occurs in activities from which a nucleus pulposus injury is not possible it can also only seldom be the result of an accidental injury However, in every instance one should accurately determine whether an aggravation of an existing disc herniation has occurred In the majority of acute lumbagos an accident is not a deciding factor The backache begins suddenly and is not related to an accident Therefore, it is not

[1] Ehalt W Die richtige Anwendung des Wortes Osteomyelitis Monatschr Unfallheilk 47 378—380 1940

recognized as an industrial accident It is important for every general practitioner to know this fact and therefore to omit a report of industrial accident and also to inform the patient of this fact so that he does not have any false hopes of a compensation In this way one can avoid much useless paperwork and irritation and save the patient much disappointment

In addition to lumbago there are also sprains in the lumbar and sacral regions These occur for instance when two persons are carrying a heavy beam or some other heavy burden and one suddenly lets go The resulting *sprains, as a rule, heal quickly Only exceptionally do severe injuries result* from such an accident Thus I have seen two men, who carried a stove and slipped, both sustain a fracture in the lower thoracic vertebral column Such occurrences are however very rare On the other hand it often happens that someone *falls* on his back or is struck in the back by a heavy object at work Fractures of the vertebral bodies and the spinal processes and transverse processes can thus occur The complaints following such injuries should never be designated as lumbago traumatica, but rather as sprain or contusion of the back including mention of any fractures that may have been associated

In addition there is a long list of disorders that formerly were attributed to accidents However, I cannot go into greater detail here In order to avoid the unpleasant *compensation suits* as much as possible, I have roentgenograms made from both sides even in the case of minor injuries in the area of the spine in order to demonstrate without question abnormal changes of bones and joints that were already present at the time of the injury, so that they are not later attributed to a minor accident On the other hand I will be able to prove that changes that develop after a certain period of time in the area of the injury previously normal, are to be attributed to the accident

The answer to the question of relationship to injury in *purulent spreading cellulitis*, in infections of the fingers and the suppuration along their *tendon sheaths* requires special care and exactitude They can only occur if the skin is injured and pathogenic organisms have entered via the site of injury The relationship is clear if one has first seen the patient with a fresh injury and then one or more days later with inflammation It is much commoner, however, that the patient does not appear for examination and treatment until an infection follows an unlikely injury such as can occur daily in manual work without any further manifestations Recognition of an inflammation as industrial accident requires *strict and conclusive* proof, that the injury occurred during work or that an injury that was not sustained during work became infected during work The Reichsversicherungsamt has now given up its former strict viewpoint and now requires as in most other accident occurrences only proof of strong probability

Decision of the Reichsversicherungsamt of September 10, 1937, Ia 2960/36

"In cellulitis an industrial accident may be considered causative, when the circumstances are such, that considering general experience, the injury or infection in all probability occurred at work

Or decision of the Reichsversicherungsamt of September 15, 1940, Ia 1336/39

In the presence of multiple skin injuries on the hands, that resulted in part from weathering influences in the form of tears and cracks and in part from the industrial occupation, of which each comes under consideration as port of entry for the pathogenic organisms, no strict proof is required for the time and the circumstances of development of just that injury, through which these organisms gained entry "

At the former decisions one often had the impression that inflammations in the region of the fingers and hand were too often disallowed as industrial accidents, since it must repeatedly be emphasized, that anyone who works 8 to 12 hours a day, during which time he can sustain a minor injury at any time, runs more risk here than away from work As soon as a reasonable suspicion arises that the injury and the following inflammation originated away from work, these doubts must be included in the report to the trade associations

Mayr[1] commented about this problem in a similar manner and gave several examples

Arthrosis deformans or *deforming joint inflammation* is an exceedingly widespread malady It can result as manifestation of wear and tear and is therefore common among old people Then it occurs as sequel to rheumatic diseases and after prolonged influence of wet, cold, living in damp sunless rooms and overexertions It also occurs after injuries, when a joint has been dislocated or fractured or if it has been infected In addition it occurs particularly in the region of the legs and vertebral column, when fractures have healed with shortening angulation or rotation After dislocations it sometimes does not occur until after 2 to 5 years and after malunited fractures after 10 to 20 years as I proved in 1942 in Der Chirurg'

The question, whether an arthrosis deformans is the result of an injury, often poses the most difficult decisions for us However if we routinely take roentgenograms in both main planes in every accident that has involved a joint or its surrounding area as soon as the work is interrupted, we can always determine without question whether the bones and joints were normal or already diseased at the time of injury In questionable cases comparison films are made of the other site of the body When changes appear later that are limited to the injured joint, the question regarding the etiological relationship is easy to answer One must remember, however, that an already diseased joint can be made temporarily worse or, for example, after severe joint fractures, permanently worse

If after an injury in the region of the fingers or the hand, for instance after an ordinary fracture of the radius in individuals over 40 years of age a painful limitation of motion of the ipsilateral shoulder occurs, while all other joints remain well, this is unquestionably a complication of the injury (see Vol I/pp 796, 803—805) If a so-called scientific disability evaluation with references to much literature regarding foci of infections etc wants to

[1] Mayr S Wann ist eine Zellgewebsentzundung Betriebsunfall? Monatschr Unfallheilk *50* 232—236 1943

Bohler L Der schadliche Einfluß von Achsenknickungen auf die Gelenke des Beines Chirurg *14* 109—111 1942

prove that the disability in the shoulder has no relation to the accident, the injured patient is done an injustice if the line of reasoning of such a disability evaluation is accepted

Considerable confusion still exists today *in the diagnosis, treatment and* disability evaluation of *meniscus injuries* Various types of injuries of the knee joint can result from accidents, namely in addition to gross fractures of the femur, the lower leg and the patella and in addition to dislocations of the knee joint and the patella that are relatively easy to recognize, there are contusions and tears of the capsule and the soft tissues, sprains and tears of the extensor apparatus, the lateral ligaments, the cruciate ligaments, the menisci and small fragments torn from the bone Several of these injuries can occur at the same time, for instance tears of the medial collateral ligament and of the cruciate ligaments with avulsion of a bony fragment Formerly these injuries could not be differentiated, and they were lumped together as *"internal derangement of the knee" In the last decades we have learned* to differentiate the various types of injuries from one another especially with the aid of roentgenograms In many books the mechanism of their origin and their signs are however variously described and therefore confusion remains in their recognition This is especially true in meniscus injuries The requirements which for instance have been set for the recognition of a meniscus injury as an industrial accident do not in the main agree with the actual facts, as I have brought out on pages 1612—1614 Since, however the diagnosis of an injury or diseased state is an absolute prerequisite for its proper treatment and correct disability evaluation, in this condition errors in treatment and errors in evaluation of disability not uncommonly occur *Above all, it should be brought out that the diagnosis of meniscus injury is* made much too often According to my experience, of 100 injuries of the knee only 4 to 6 are meniscus injuries If one adheres to the criteria given on pages 1591—1595, the correct diagnosis can almost always be made (in our series in 93 97% of the cases operated upon) If one carries out proper treatment (operative removal of only that portion of the meniscus which has been torn off and not removal of the entire meniscus) (see pp 1596—1602) after correct diagnosis most of them heal in a relatively short time, namely in 6 to 7 weeks, without significant permanent damage This can be seen from the fact that of 57 meniscus injuries of the years 1926—1932 that were reevaluated by Streli after 18 to 20 years only one receives permanent dis*ability compensation (see p 1620)*

It can become dangerous for the injured person if the diagnosis meniscus is made, because then the injury is disallowed as an industrial accident by many insurance adjustors and disability evaluators, and some surgeons immediately want to extirpate the meniscus

The following requirements have been defined by many for the recognition of a meniscus injury as an industrial accident The force must have acted directly upon the knee and must have been considerable The patient must show immediate signs of severe injury, namely, pain, inability to bear weight, inability to continue work and consultation of a doctor The effusion

on aspiration of the knee joint or at early operation must be bloody The microscopic examination may show no marked degeneration'

Since the mechanism of origin and the symptoms of a true meniscus injury are entirely different (see pp 1584—1588), according to the above conditions as a rule it would have to be disallowed as an industrial accident

Our views concerning the etiology, diagnosis, treatment and disability evaluation of meniscus injuries are described in detail in the book by Kromer[1]

VII STATISTICS

90,078 inpatients and 655,950 outpatients, 746,028 altogether, were treated in the 31 years from 1926—1956 The following table shows the yearly increase until 1931 This is followed by a decline, because as a result of the world economic crisis unemployment rapidly increased, and there are fewer industrial accidents when less work is done From 1933—1938 the number again increased rapidly, because, in spite of the fact that unemployment increased, more and more injured persons sought treatment at the Accident Hospital In 1944 a peak was reached In 1945 a rapid decline followed because many industrial concerns were closed Then followed a rapid increase until 1956 In 1950 the peak of 1944 was again reached

The number of hospital admissions could not increase as rapidly, because the number of beds has remained unchanged since 1940 In order to cope with the influx we endeavored to continually shorten the hospital treatment time by improved methods and new procedures, for instance by femoral neck nailing and intramedullary nailing as well as by treating as many as possible ambulatory

On march 19, 1952 the number of outpatients and inpatients had reached 500,000

	Admissions to the Accident Hospital	Admissions to the Outpatient Service
1926	893	2,946
1927	1,311	3,711
1928	1 776	5,191
1929	1,792	6,936
1930	1,849	7,398
1931	1,988	7,534
1932	1,816	6 478
1933	2,012	6,801
1934	2,632	7,849
1935	2,668	8,687
1936	2,788	9,802
1937	2,931	10,537
1938	3,247	14,528
1939	2,913	16,454
1940	2,993	19,713
1941	3,054	23,582

[1] Kromer K Der verletzte Meniscus Bd 3 Wien Verlag Maudrich 1955

1942	3,075	24,298
1943	3,797	31,325
1944	3,585	32,670
1945	2,293	13,762
1946	2,597	15,818
1947	2,789	20,363
1948	3,538	24,897
1949	3,857	29,535
1950	4,068	31,955
1951	4,167	37,382
1952	4,025	41,558
1953	3,886	46,062
1954	4,316	49,290
1955	4,393	53,471
1956	3,020	45,417
	90,078	655,950

The number of inpatients decreased because the number of beds has been reduced to 70 during remodelling The number of outpatients has decreased, because the new Accident Hospital was put into operation at the end of January 1956

The operation protocols of 1925—1938 were unfortunately lost as a result of an act of war

In the 17 years from 1939—1955 among others the following operative procedures were carried out

	1939—54	1955
Wound excision with wound suture	76,477	8,354
Incisions and drainage of infections	16,316	1,057
Removal of fingernails and toenails	27,055	2,324
Amputation of fingers	8,270	517
Amputations through metacarpals	737	28
Amputations of forearms	104	2
Amputation through upper arm	44	6
Amputation of toes	527	11
Amputation through metatarsals	56	2
Amputation of lower leg	178	9
Amputation through thigh	127	4
Tendon suture		
Flexors	227	33
Extensors	1,058	155
Achilles tendon	131	26
Nerve suture	535	148
Skin graft		
Pedicle grafts	419	172
Split grafts	472	33
Pinch grafts	1,300	177
Laparotomies because of injuries	179	18
Nailing of femoral neck fractures	606	34

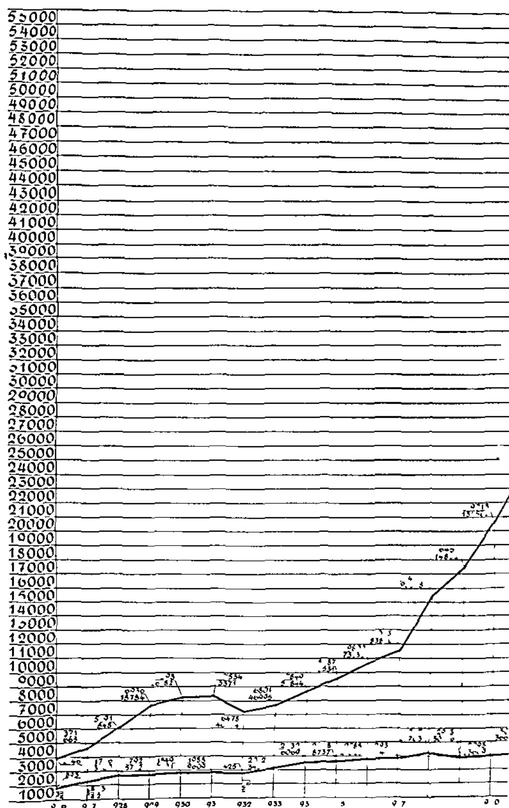
Intramedullary nailing	429	30
Patella suture	170	11
Olecranon suture	140	10
Meniscus resections	811	62
Non unions	437	20
Bone grafts	306	65
Arthroplasties	104	5
Recurrent dislocation of the shoulder	110	9
Tendon grafts	121	42
Blood transfusions	971	191

The following fresh fractures were treated in the 30 years 1926—1955

	1926—54	1955
Skull fractures	1,956	86
Vertebral fractures, body, transverse processes, spinous processes	2,690	163
Fractures of the sternum	52	0
Fractures of the pelvis	1,047	72
Clavicle fractures	2,281	278
Scapula fractures	489	28
Fractures of the humerus	4,434	439
Fractures of the forearm	15,549	1,930
Navicular fractures and other carpal fractures	4,067	463
Fractures of fingers	28,592	1,287
Fractures of the femur	2 879	271
Fractures of the patella	911	64
Fractures of the lower leg	13,900	1,378
Fractures of the calcaneus	1,592	97
Fractures of tarsals	713	29
Fractures of metatarsals	5,699	316
Fractures of toes	15,828	889
	107,475	8,192

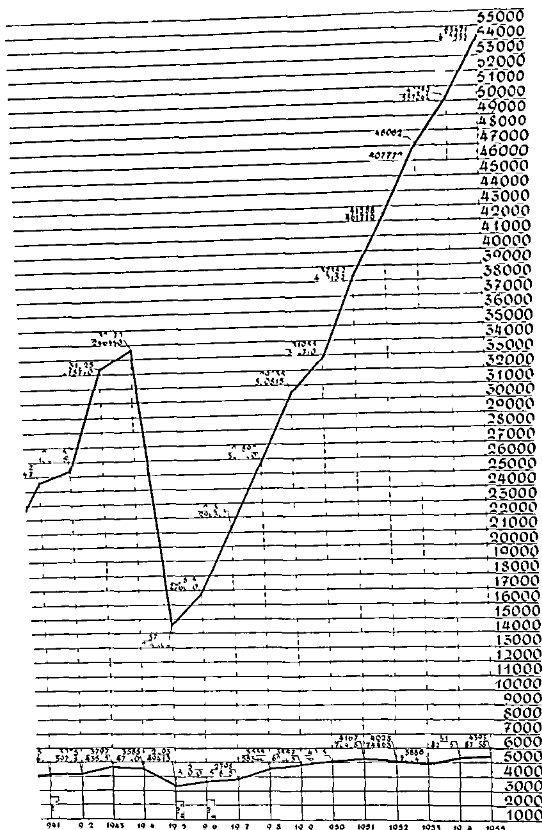
In the 30 years between 1926—1955 the following fresh dislocations came for treatment

Clavicular dislocations	546	55
Shoulder dislocations	1,515	178
Elbow dislocations	519	44
Dislocation of the distal radio ulnar joint	53	6
Dislocation of the wrist	33	2
Perilunate dislocations	184	7
Dislocations of fingers	695	79
Dislocations of the hip	124	13
Dislocations of the patella	94	12
Dislocations of the knee joint	59	2
Partial dislocation of the ankle	1,731	110
Subtalar Dislocations	87	6
	5,640	514



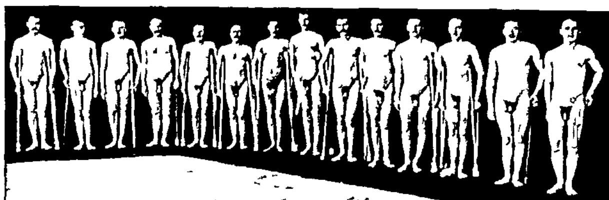
3091

FIG 3090 – The lower curve shows the number of inpatients and the upper that of outpatients treated annually in the Accident Hospital from 1926—1940 The upper number indicates the number admitted in the last year and the lower that of all years



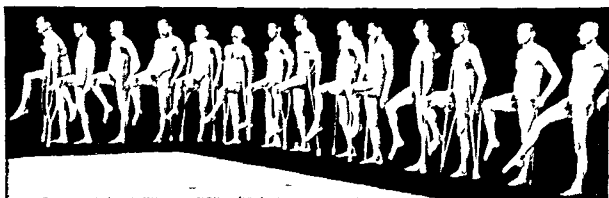
3092

FIG 3092—Continuation of the curve of fig 3091 for the years 1941—1955 The number of inpatients has not changed significantly because it is dependent on the number of available beds The number of outpatients is shown to have steadily increased Only in 1945 it shows a steep decline because most industries and traffic were idle after the war



3094 August 18 1917

Fig 3094—1—6 closed fractures of the femur 7—14 gunshot fractures of the femur 2 to 6 weeks after removal of traction The roentgenogram is sketched on the sound leg These *are not selected cases but rather all patients who achieved healing within a four week period*



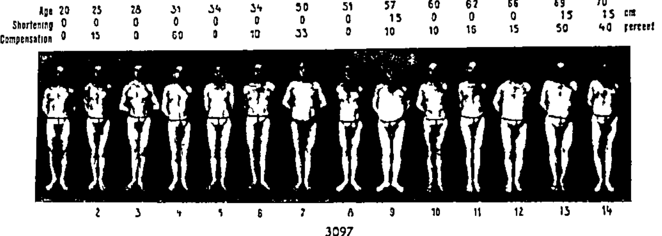
3095 August 18 1917

Fig 3095—With the exception of cases 6 and 14 all could bend their knee over 90° Case 14 was not brought in until after 3 months



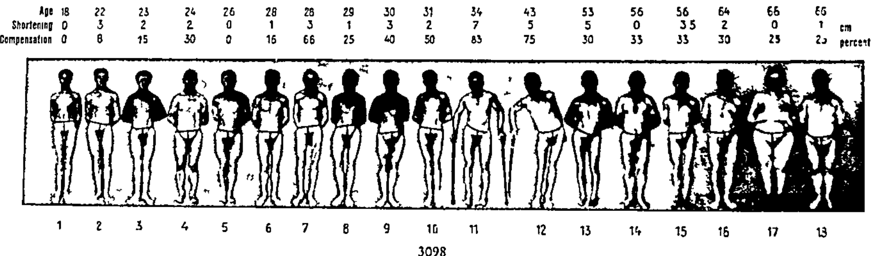
3096 August 18 1917

Fig 3096—Muscles in all are strong With the exception of case 13 active extension of the knee joint is not yet possible This usually is not possible before 2 to 3 months No pes equinus



3097

Fig 3097—Photographs of the 14 insured patients fractures of the femur treated in the Accident Hospital in the year 1927 with age shortening and compensation after 2 years indicated Thereafter all pensions below 20% were dropped Of the 14 only 3 have shortening of 1 to 2 cm, only four draw disability pension of more than 20%



3098

Fig 3098—Photographs of the 18 insured fractures of the femur treated outside of the Accident Hospital with age shortening and disability compensation after 2 years Of the 18 patients 11 have shortening of 2 to 7 cm, 13 receive a pension of more than 20%

Results of Treatment at the Accident Hospital

Cerebral Concussion Cerebral concussion formerly caused me considerable thought, because I could not explain the symptoms that many patients presented Since it struck me that as a rule only insured individuals complained about headache and other disturbances, while the non-insured usually had no complaints, I and many others gradually became convinced that the symptoms that occurred in the insured patients were not the result of the accident, but rather were simply the result of being insured After thorough discussions with Professor Hoff and all surgeons, neurologists and disability evaluators in Vienna we decided not to pay further compensations for residuals of cerebral concussion alone if we were able to exclude severe brain injury after thorough examination Since then the insured as a rule do not complain of headache either Duration of bed rest and total disability were very much shortened

The average duration of bed rest in 1945 was only 4 2 days, duration of hospitalization 6 days and the entire duration of treatment 22 2 days In 1953 the average duration of bed rest was only 3 9 days, the duration of hospitalization 5 9 days and the duration of the entire treatment 19 6 days

The number of compensation cases is shown in the following table

	1 1 48 to 30 6 49	1 3 51 to 30 8 52
Insured industrial accidents	225	239
Compensations because of cerebral concussion		
Permanent disability	3	0
Temporary compensation	15	0
In addition, compensation sought and disallowed	2	8
Appeals	6 cases with 10 appeals	2 cases
Of these awarded compensation	5	0

Psychological Treatment If after meticulous examination we have determined that no severe brain damage is present, we tell the patient that he fortunately only has a cerebral concussion and that he will soon be well and symptom free

Treatment with Drugs Since 1950 we have given only harmless headache powders as long as there have been complaints of headache and dizziness as a result of the shock and the vasomotor disturbance We have abandoned intravenous injection of Osmon and similar agents because we have seen that the early complaints do not disappear more rapidly with their use We also do not use an icebag on the head I have described our treatment routine at the Deutsche Chirurgenkongreß in 1954 [1] In the Austrian Codex for drugs more than 300 remedies for the treatment of cerebral concussion and of the post concussion syndrome are listed and new ones are being continually added

[1] Böhler L Behandlung und Begutachtung der Gehirnerschutterung Erfahrungen an 3000 Fallen Langenbecks Arch Dtsch Ztschr Chir *279* 180—187 1954

Cerebral concussion is not only a psychology problem but also a financial problem According to Simon Weidner[1] no fewer than 32,000 cerebral concussions were reported to the German Trade Associations in 1953 Twenty million D marks were paid for treatment and compensations because approximately every other one was awarded a compensation If we would still pay compensation for cerebral concussion in Austria it would cost about 3 million DM or 18 million Austrian shillings a year In addition to this injured persons who receive a pension for cerebral concussion are usually dissatisfied and often appeal to higher courts

Compensation neurosis are exceptional because of the psychological influence and the planned avoidance of pain by local anesthesia, uninterrupted immobilization and painless exercise

Skull fractures are currently being evaluated The results seem to be fairly good

Blunt Trauma to the Abdomen For decades it has been claimed that the life of persons with injuries of the inner organs would be in jeopardy if they came to an Accident Hospital The following comparative statistic shows that this is not the case (see p 2264)

From this statistic it can be seen that we not only have by far the greatest number of published cases of blunt abdominal trauma that have been operated upon, but that our results are also the best It is thus proved that these injuries can also be suitably treated in an Accident Hospital Breitner once wrote that an accident surgeon would never be in a positon to operate upon a case with an injury of the biliary tract Among our cases was a tear of the cystic duct The patient recovered uneventfully after removal of his gallbladder

Organization of Wound Treatment and Gathering of Statistics Since we know that infection after fresh accidental injuries can usually be avoided by suitable technique, we have organized everything in the Accident Hospital in such a way, that wound infections can be reduced to a minimum

In order to immediately care for every injured person all services of the hospital are in operation day and night, Sundays and holidays There are always enough doctors with adequate experience on duty, namely currently one of the four Oberarzte and three of the younger doctors must be in the hospital at all times including nights I myself live in the hospital and as a rule am available at all times of the day or night An X-ray nurse and two surgical nurses are *always on duty* nights and Sundays The instruments are always sterile Thus every injury can be immediately adequately cared for even at night

All ambulance units and all factories are urged to bring the accident victims immediatley They do not first go to some first aid station where they are bandaged and observed, but rather are brought directly to us without delay We are thus in the fortunate position of having the major portion of the insured industrial accidents delivered to us within the first hour if they are from Vienna and within the first six hours if they are from the surrounding territory

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[1] Simon Weidner R *Ist die Commotio ein Problem der Psychologie oder der Unfallheilkunde?* Heft Unfallheilk *48* 77—80 1955

In this manner, as a result of suitable organization of the ambulance service and of the hospital, we have been able to treat properly all fresh wounds within the first six hours, that is, all larger wounds are accurately excised and usually closed with sutures or in the case of contused skin partially closed with loose sutures and immobilized, the superficial ones are only bandaged and if necessary also immobilized The further treatment is so arranged that we can observe the course and final result at all times and can do follow-up examinations

Author	Time covered by the survey	No of operated cases	Deaths	Mortality in %
Lauer and Schnebel Stadtkrankenhaus Nurnberg	1910—1925	53	25	47%
Wyss Kanton Hospital Aarau	1908—1927	73	30	41%
Just * Surgical University Clinic Innsbruck	1924—1929	26	7	27%
Scholl * I Surgical University Clinic Vienna	1924—1934	38	17	44%
Muller E Surgical University Clinic Heidelberg	1927—1936	58	29	50%
v Seemen * Surgical *University Clinic Munich*	1928—1936	70	26	37%
v Avancini I Surgical University Clinic Vienna	1939—1944	22	7	32%
Slany Bohler Accident Hospital Vienna	1926—1947	94	39	41 5%
Poigenfurst Bohler Accident Hospital Vienna	1948—1956	75	19	25 33%

* The number given was calculated from the original publication after exclusion of renal injuries

Lauer O and Schnebel Beobachtungen an 55 Fallen stumpfer Bauchverletzungen Beitr Klin Chir *137* 441—453 1926
Wyss H Über die stumpfen Bauchverletzungen der chirurgischen Abteilung der Kant Krankenanstalt Aarau in den Jahren 1908—1927 Schweiz med Wschr 1390—1397 1929
Just E Über subkutane Bauchverletzungen Arch klin Chir *160* 327—347 1930
Scholl R Über Stich und Schußverletzungen des Abdomens Mitt *Granzgeb Med* u Chir *44* 354—389 1936
Muller E Bauchverletzungen Erg Chir u *Orthop 31* 589—666 *1938*
v Seemen H Über die Tatigkeit der Unfallstation der Munchener Chirurgischen Klinik von 1928 bis 1936 Arch klin Chir *193* 321—324 1938
v Avancini L P Über stumpfe Bauchverletzungen Wien Klin Wschr *58* 91—92 1946

All patients with open fractures, with relatively large wounds and most severe finger and hand injuries are admitted to the hospital for several days until one can see that no wound complications are going to occur This is especially important in winter in those injuries in which the circulation is poor If one sends patients with extensive flap wounds or old patients into the cold air and when their housing conditions are poor and they cannot heat adequately, necrosis of poorly nourished skin flaps and late infection of wounds often occur, whereas they can recover under the more satisfactory conditions of the hospital with even bed temperature, elevation and rest In this manner one can save many fingers and hands that would otherwise be lost

All injured patients that are sent home must under any circumstances present themselves on the next day and later every second or third day If pain increases, lymph node swelling, lymphangitis or fever appear the bandage is opened Otherwise the wound is left undisturbed for 1 to 2 weeks The daily change of dressings and especially bathing that is practiced in many places often disturbs wound healing (see example 6, p 2172)

In addition to the general information (name, age, residence, occupation mode of injury) an exact description of the operation is immediately dictated by the doctor who has cared for the wound for the patient s individual operation protocol This includes extent of the wound in cm, exact location, depth complications such as involvement of tendon sheaths or joints, bone injuries, partial or complete severence of nerves and tendons and of important vessels, opening of body cavities, and so on The final result is later entered into the same book by the ward doctor or the outpatient doctor For this purpose we use the following classification

1 Per primam (p p) healing, namely completely smooth healing without any complications

2 Stitch infection, i e, the wound itself healed per primam (p p) one or another stitch site is reddened or abscessed

3 Necrosis of the wound edge, i e, dry necrosis without infection

4 Extensive dry skin necrosis, also without infection

5 Per secundam (p s) healing, that is local infection in which the sutures had to be removed early, but without progression of the infection

6 Secondary infection originating in drain sites and dry wound necroses

7 Healing per granulation used for those wounds that were not sutured primarily, for instance in superficial loss of skin or by gunshot wounds

8 Progressive infections, namely abscesses, progressive tendon sheath infections, as well as spreading cellulitis in the region of the injury

(3 and 4 are usually the result of extensive contusions)

The Oberarzt reviews these operation protocols weekly, on the one hand to uncover and correct possible obscurities, and on the other hand to classify the *wounds according to their severity* namely according to the following criteria

a Ordinary wound excision (extending into the subcutis)

b Involvement of tendon sheath or joint

c Tendon injuries with intact function
d Tendon severence with loss of function
e All nerve and vessel injuries
f Open fractures of small bones
g Open fractures of the long hollow bones or of other large bones (skull, pelvis, etc)
h Opening of large body cavities

The following *control* proved very important, instructive and useful A report is made monthly about the results of wound treatment according to the eight points listed above and in points 2 to 8 it is noted how the injury occurred and who cared for the wound The results of this statistic were very interesting It became apparent that the infection was not dependent on the location or the mode of injury, but rather that frequent infections occurred under the care of certain doctors This is proof that they had not excised the wounds thoroughly enough Necrosis of the stump in finger amputations occurred with certain doctors They made the skin flaps too short or sutured with too much tension Lack of or inadequate drainage also was sometimes found as cause of an infection, especially in wounds with cavities, muscle injuries or in injuries of individuals who work with meat or fish

Since in this way it was possible for us to establish the cause of these infections, the correction was easy to find the doctors involved were required to work with help or under the supervision of older and more experienced doctors Usually younger doctors were involved that did not yet have enough experience Occasionally, however it happened that a doctor often had difficulties in wound treatment, namely that he was unable to acquire the necessary technique and dexterity In such a case there was no alternative but to recommend that he select a different specialty of medicine

As early as 1938 in the sixty second session of the Deutsche Gesellschaft fur Chirurgie I[1] spoke about organization and instruction At that time Kirschner criticized me saying that it was irresponsible to dismiss an assistant, if in a certain period of time a certain number of infections occur in cases treated by him, because at that time I had written that we have the rule that every doctor be dismissed, who has more than three infections following wound excisions in one month However, in the 31-year history of the Accident Hospital no doctor was dismissed for this cause because his colleagues saw to it that after the third infection which was exceedingly rare, he carried out no further wound excisions during that month Thus the goal was achieved that those less suited took greater pains to work more accurately in order to spare the patient complications

Use of Antibiotics Antibiotics are a very valuable adjunct to the treatment of severe bone and soft tissue injuries and infections that are already present, especially in those of tendon sheaths In simpler wounds they are not neces-

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1 Bohler L Aussprache zu Kirschner Der Verkehrsunfall und seine erste Behandlung Arch Klin Chir *193* 66—67 84 1938

sary Therefore I use them in only about 10% of all cases after thorough wound excision It must repeatedly be forcefully emphasized that the important principles of treatment of fresh wounds are accurate excision, skin closure without tension uninterrupted immobilization and painless exercise In infected wounds sometimes immobilization alone, and in the presence of tension, its release with a suitable incision or by aspiration suffice, and that the use of antibiotics is only an adjunct even though a very valuable one Chemical disinfectants are always harmful

The use of antibiotics is also a financial problem In 1954 with a census of 140 beds with 55,000 patients days we have spent 165,000 shillings (27,500 DM) for antibiotics This amounts to 3 shillings (0 5 DM) a day I have charged all the expenditures for antibiotics to the inpatients, because we use them much less often for the outpatients Of the sum spent for penicillin, streptomycin, etc hardly a tenth is used for patients with freshly excised wounds We have used these agents chiefly for those 1630 patients who have come to us with infected wounds, in whom we had to perform incisions, and then for those with extensive bone and joint and tendon operations

In order that not too large amounts of antibiotics are given and their use is not extended for too long a period of time, every case is reported to me daily Otherwise too I use very few medications Thus, for instance, in my rehabilitation center Stollhof in Klosterneuburg-Kierling with 90 beds and 32,639 patients days in the year 1954 I used only 2849 shillings (475 DM) for medications That is 8 73 groschen (1 45 pfennig) daily for each patient Perhaps they look so healthy there because they receive so few medications and get good food instead

Results of Wound Treatment In the five years 1926—1930, 14,182 open injuries were treated Arranged according to body areas

	Fresh	Old and infected	Altogether
Head	1427	33	1460
Trunk	171	41	212
Upper arm	76	19	95
Forearm	724	172	896
Hand	1571	497	2068
Fingers	6424	1240	7664
Thigh	108	12	120
Lower leg	503	123	626
Foot	559	114	673
Toes	330	38	368
Total	11,893	2 289	14,182

Of the 6,424 finger injuries an infection extending to the forearm occurred only once

Of the 14,182 open injuries the following had amputations or died

c Tendon injuries with intact function
d Tendon severence with loss of function
e All nerve and vessel injuries
f Open fractures of small bones
g Open fractures of the long hollow bones or of other large bones (skull, pelvis, etc)
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Use of Antibiotics Antibiotics are a very valuable adjunct to the treatment of severe bone and soft tissue injuries and infections that are already present especially in those of tendon sheaths In simpler wounds they are not neces-

[1] Böhler L Aussprache zu Kirschner Der Verkehrsunfall und seine erste Behandlung Arch Klin Chir *193* 66—67 84 1938

Spreading Wound Infection In 80 of the 81 wound infections the infection stopped spreading on removal of the sutures Incision because of spreading of the infection had to be done in only one case

Thromboses and Emboli Currently the chief danger after injuries is no longer infection but thrombosis and embolism I have the impression that they have increased considerably since the introduction of antibiotics

Ball [1] has collected the wound complications that occurred in our 765 wound excisions in April 1955 He found that 10 (1 38%) became infected, 3 (0 42%) developed skin necroses, and 7 (0 96%) developed unimportant stitch abscesses There were no deaths, no amputations, no spreading infection requiring incision, and no permanent damage resulting from infection

The following table shows a comparison of the deaths from infection and gas gangrene after fresh and old accidental wounds in cases which were admitted to our hospital, with those of Billroth and Clairmont

	No of injured persons admitted to the hospital	Deaths from infection and gas gangrene		
		fresh at admission	infected at admission	total
Billroth [2] 1860—1876	1672	—	—	276 (16 5 %)
Clairmont Meyer [3] Zürich 1920—1929	2476	14 (0 56%)	26 (1 05%)	40 (1 6 %)
Ehalt [4] Bohler Accident Hospital Vienna 1926—1930	3698	2 (0 07%)	3 (0 11%)	5 (0 18%)

Since 1945 we have had no deaths from sepsis or gas gangrene in patients with fresh wounds or wounds already infected when first seen

The results of treatment of open fractures of the long tubular bones are usually used as a criterion of wound treatment

Deaths While according to Volkmann [5] in the preantiseptic era 40% of all open fractures died from wound infection according to the compilation by

[1] Ball Über Wundbehandlung und Storungen der Wundheilung im Unfallkrankenhaus Wien Munch med Wschr 97 1251—1255 1955

[2] Billroth Th Chirurg Klinik Berlin A Hirschwald 1869 1870 1872, 1879

[3] Clairmont Meyer Zur Verhutung und Behandlung der pyogenen and putriden Infektion akzidenteller Wunden Munch med Wschr 78 1937 2037 2073 1931

[4] Ehalt W Die Todesfalle und Amputationen des Unfallkrankenhauses und der Arbeiter unfallversicherungsanstalt fur Wien Niederosterreich und Burgenland in den Jahren 1926 bis 1930 unter besonderer Berucksichtigung der Sepsis nach frischen offenen Verletzungen Hefte zur Unfallheilk 14 1—55 1932

[5] Volkmann R Sammlung klinischer Vortrage Nr 117—118 Leipzig Verlag Breitkopf u Hurtel 1877

		Dea hs from infections	Deaths from gas gangrene	Deaths from tetanus	Primary amputa tions	Secondary amputations without infection	Secondary amputations because of infection
Fresh cases	11,893	1	1	2	16	7	0
Old cases	2 289	3	0	0	0	4	2
Total	14 182	4	1	2	16	11	2

The number of open injuries that came for treatment rose to more than 130,000 by the end of 1955

Of the 10,625 cases of 1954 I wish to *present only those 7542* cases with major wounds that were closed after thorough wound excision More than half were finger and hand injuries with hundreds of open fractures and open joints including well over 1000 head wounds and 13 open skull fractures In addition there were severe, often multiple soft tissue lacerations and extensive skin abrasions 102 open fractures of the long tubular bones, 39 large and 209 small open joint injuries of fingers and toes Those who had amputations because of the severity of the injury are not included

No of cases	Healed p p	Healed p s	Skin necroses	Stitch abscesses
7542	7353 (97 5/)	81 (1 07/)	60 (0 79%)	48 (0 63/)

The majority of the 60 skin necroses and all 48 stitch abscesses were of no importance

Deaths from infection	Amputations because of infection	Incisions because of spreading infection
0	8 *(6 finger 2 lower leg)*	1

Of the 81 infections 56 (more than two thirds) and of the 60 skin necroses 23 (more than one-third) occurred in hand injuries The cause in the greater majority was skin necrosis because too little was amputated primarily

Deaths Of the 7542 patients whose wounds had been excised and closed none died from a wound infection

Amputations In each of six patients a finger had to be amputated Skin necroses in the presence of comminution of the bones and joints caused the majority of the infections In addition one patient with severe open fractures of the tarsals had an amputation through the lower leg and a second because of an open fracture of the ankle with a large skin defect because in both infections had resulted from extensive skin necroses In these eight cases primary amputation because of the extensive skin damage would have been better No amputations had to be done for *spreading infection or for sepsis*

	No of open fractures of the extremities	Died of generalized infection	Primary amputations	Of these no died of generalized infections	Secondary amputations	Of these no died of generalized infections	Survivors not amputated
1 Surgical University Clinic, Zurich 1860—1930 (Schlapfer[1])							
Billroth 1860—1861	219	86 (39%)	72 (33%)	33 (46%)	26 (12%)	23 (90%)	35 (15 9%)
Rose 1868—1871	102	8 (9%)	30 amputated (29%)		Died of generalized infection 3 (10%)		64 (62 7%)
Kronlein 1881—1884	68	5 (7%)	16 (19%)	1 (6%)	—	—	41 (69 1%)
Kronlein 1899—1910	228	10 (4%)	12 (5%)	—	16 (18%)	4 (25%)	190 (83 3%)
Sauerbruch 1911—1918	137	1 (0 8%)	14 (10%)	—	7 (3%)	—	115 (83 9%)
Clairmont 1919—1929	310	5 (5%)	52 (17%)	1 (0 5%)	27 (8%)	9 (33%)	226 (69 7%)
2 Koch 1929	213	12 (5 6%)	16 (7 8%)	—	10 (4 7%)	—	175 (82%)
3 Schmidt[3], 1928	116	8 (6%)	18 (15 5%)	5 (27 7%)	19 (16 3%)	5 (26 3%)	71 (61 2%)
4 Bohler 1916—1918 Gunshot fractures	601, of which 513 (85%) arrived infected	6 (0 9%)	0	0	4 (0 66%)	0	591 (93 3%)
5 Ehalt Bohler, Accident Hospital, Vienna 1926—1934	307	1 (0 33%)	11 (3 6%)	0	3 (0 48%)	0	292 (95 11%)

[1] Schlapfer K Die Oberarmknochenbruche an der Zuricher chirurgischen Klinik in den letzten 20 Jahren (1899—1919) Arch orthop Unfallchir 20 135—212 1922

Koch L Die Primare Wundnaht bei offenen Knochenbruchen Arch orthop Unfallchir 27 61—80 1929

[3] Schmidt H Zur Behandlung komplizierter Arm und Beinfrakturen Dtsch Zschr Chir 209 382—390 1928

Ehalt[1] only one of our 307 cases died from infection, which, however, did not originate in the fracture site but in an unnoticed wound on the other leg One patient died from tetanus and no one from gas gangrene

Amputations There was one amputation through the lower leg because of gas gangrene No amputations were done because of sepsis

Infections Of our 307 fractures, 11 (3 6%) *developed severe infection that* required surgical attack Of the 23 open fractures of the femur and the 24 open fractures of the upper arm none developed an infection

Spreading phlegmons extending beyond the involved portion of the limb were never observed

Erysipelas never occurred, either during treatment or during the after-treatment

Sequestra and fistulae were not found in a single case at the time of follow up examination

Significant shortening developed only in two open fractures of the femur

Pseudarthroses developed in eight cases (2 6%) Of these three were successfully treated by operation, so that at follow-up evaluation only five (1 6%) showed no bony union

The *functional results* of our open fractures are to a great extent better *than those presented in many collective statistics of closed fractures, as can be* seen in the tables and especially in the numerous photographs and roentgenograms of the book by Ehalt

Compensations 161 of the 307 open fractures were insured industrial accidents Of these only 25 (15 5%) receive permanent disability pensions

The often voiced objection that we only have mild cases to treat is negated by our photographs and roentgenograms (Vol I/figs 182—191, 202—240 294—301, 830—833 864—874, 881—888, 1032—1035, 1133—1140, 1173 to 1180, 1195—1198, 2159—2164, 2166 l—n, 2166 qu—t, 2253—2262, 2356 to 2359, 2488—2504, 2574—2575 a, 2576—2581 c, 2731—2744) In addition in the book by Ehalt are presented uninterrupted series of roentgenograms and photographs of all of our *open* fractures of the femur Of the other *open* fractures the book presents photographs of those with complications A comparison of our deaths and amputations after open fractures of the long tubular *bones with those of other clinics can be seen from the table on page 2271*

An additional 17 of my 601 gunshot fractures presented in this table died from other causes Counting these there are 23 (3 8%) deaths and 4 (0 66%) amputations Thus, 574 (95 5%) escaped with life and limb

Open Knee Joint Injuries Of 100 open knee joint injuries, one case with severe comminution of the joint died of sepsis The wound had not been excised Not a single amputation was done In three cases infection developed Two of these three cases were not recognized as open knee injuries and were therefore not excised properly 96 healed without complication Among these were 8 open fractures of the femur, 5 open fractures of the lower leg and 10 open fractures of the patella

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1 Ehalt W Behandlung der offenen Bruche der langen Rohrenknochen Wien, Verlag Maudrich 1938

industrial accidents In the meantime the number treated has risen to 2800 The shoulder and all other joints were freely mobile through their entire range in all patients The average duration of treatment was 44 5 days (compare example 2, p 2164) For comparison the numbers found by Schuppler [1] shall be presented

None of my cases received a compensation after 1½ years whereas it took two years in Scheffler's series and three years in Magnus' series In this regard I wish to add that the concept of no compensation does not completely express the result of healing, since someone with angulation has no right to a compensation if all joints are freely mobile, even though he may have discomfort while carrying burdens or from the sling of a rifle The purely cosmetic result is not considered at all in disability evaluation of a fracture of the clavicle

Source	No cases	Do not receive compensation after 2 yrs
Statistik der Österreichischen Arbeiterunfallversicherungsanstalten 1897—1911	1887	991 (52 3%)
Erfurth Cottbus 1914	264	150 (57%
Scheffler Bochum 1926	40	40 (100%)
Rieger Wurzburg 1927	89	45 (50 56%)
Stechmann Berlin Charite 1929	31	23 (74 2%)
Schuppler Bohler Wien 1935	65 (224 *)	65 (224) (100%)
		Do not receive compensation after 3 yrs
Magnus Bochum own cases 1933	131	*131 (100%)*
Magnus Bochum cases evaluated for disability	40	31 (77%)

None of our insured fractures of the clavicle received disability compensation after 1½ years Of the 1887 fractures of the clavicle which had been reported to the Austrian Workers Accident Insurance Companies in the years 1897—1911, 896 (47 7%) still received a compensation averaging 14% after two years

Fractures of the Upper Arm From 1925—1934, 103 insured fractures of the humerus were treated with the following results The fractures of the humerus of the Workers Accident Insurance Company from the years 1910—1911 are presented for comparison

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[1] Schuppler V Die Behandlungsergebnisse der Schlusselbeinbruche Arch orthop Unfallchir *35* 373—380 1935

Scheffler Beobachtungen und Ergebnisse einer funfahrigen Frakturenbehandlung Arch orthop Unfallchir *24* 298—380 1926

* 65 is the number of cases insured against industrial accidents *224 is the total number* treated

The results of treatment of 506 *fresh open* fractures of the lower leg are described on pages 1800—1805 They were reviewed by Zrubecky [1] and Krosl [2]

Open Hand and Finger Injuries Kromer [3] has collected the 1080 fresh open hand and finger injuries, which were treated by us in the second half of 1934 and presented them in his book Of these

1062 (98 3% healed without evidence of inflammation,
15 (1 4%) healed with local evidence of inflammation,
3 (0 3%) healed with progressive infection,

392 were treated by primary wound excision

Hansen's figures are presented for comparison

	Hansen [1] (Magnus) 1930		Kromer (Bohler) 1934	
	p p	p s	p p	p s
No of cases	251	68	375	17
Percent	78 7%	21 3%	96 6%	4 4%

Open Hand and Finger Fractures Of 155 patients with 217 open fractures of fingers and metacarpals, 148 (95 5%) healed without complication

Compensations for open hand finger injuries Of 1080 open hand and finger injuries, 982 were insured against industrial accidents Of these 910 (92 82%) did not receive a compensation at the end of treatment 12 (1 2%) receive a permanent pension

Of 291 closed hand and finger injuries, 242 were insured against accidents Of these 225 (92 93%) did not receive a compensation at the end of treatment No case receives a permanent disability pension

I wish to present the result of Jaros [4] of Prague for comparison

	No of cases	No disability pension at all	No disability pension after 2 years	Permanent disability pension	Died
Jaros 1930	8191	3605 (44%)	6002 (73 2%)	2184 (25 5%)	5 (0 06%)
Bohler Kromer 1934	1224	1135 (92 7%)	1185 (96 8%)	12 (1%)	0

I wish to add that the average duration of treatment was 49 days for Jaroš while it was 18 3 days for us

Closed Fractures Clavicle Fractures In the eigth years from 1926—1934 224 fractures of the clavicle were treated Of these 65 were insured against

[1] Zrubecky G Behandlung und Behandlungsergebnisse von 461 frischen offenen Unterschenkelbruchen Hefte Unfallheilk *54* 93—180 1957

[2] Krosl, W Ergebnisse der Marknagelung bei 65 geschlossenen und 45 offenen Bruchen des Unterschenkels Hefte Unfallheilk *54* 181—206 1957

[3] Kromer K Die verletzte Hand Vol III Wien Verlag Maudrich 1945

[4] Jaros M Handverletzungen und Versicherung Rozhl Chir a Gynaek Č chir *13* 270—288 1935 (Czechoslovakian) Ref Z Org Chir 72'77

industrial accidents. In the meantime the number treated has risen to 2800. The shoulder and all other joints were freely mobile through their entire range in all patients. The average duration of treatment was 44.5 days (compare example 2, p. 2164). For comparison the numbers found by Schuppler[1] shall be presented.

None of my cases received a compensation after 1½ years whereas it took two years in Scheffler's[2] series and three years in Magnus' series. In this regard I wish to add that the concept of no compensation does not completely express the result of healing, since someone with angulation has no right to a compensation if all joints are freely mobile, even though he may have discomfort while carrying burdens or from the sling of a rifle. The purely cosmetic result is not considered at all in disability evaluation of a fracture of the clavicle.

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Statistik der Österreichischen Arbeiter unfallversicherungsanstalten 1897—1911	1887	991 (52.3%)
Erfurth, Cottbus 1914	264	150 (57%)
Scheffler, Bochum 1926	40	40 (100%)
Rieger, Würzburg 1927	89	45 (50.56%)
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[1] Schuppler, V.: Die Behandlungsergebnisse der Schlüsselbeinbrüche. Arch. orthop. Unfallchir. 35, 373—380, 1935.

[2] Scheffler: Beobachtungen und Ergebnisse einer fünfjährigen Frakturenbehandlung. Arch. orthop. Unfallchir. 24, 298—380, 1926.

* 65 is the number of cases insured against industrial accidents, 224 is the total number treated.

	No of cases	No compensation after 3 years	Permanently disabled	Death during treatment	After conclusion of treatment receiving compensation died from another illness
1925—1934 treated in the Accident Hospital	103	85 (82%)	12 (12%)	2 (2%[1])	4 (4%)
1910/11 treated elsewhere	63	14 (22 2%)	49 (77 8%)	—	—

Olecranon Fractures In the 10 years from 1926—1935 we treated 45 fractures of the olecranon Nine of these were open Blechschmidt has reexamined these and worked out the following comparison statistics

	Reexamined cases	Not Operated	Of these good	Operated	Of these good
Madlener Bonn 1932	22	7	5 (71 4%)	15	8 (53 3%)
Daland Boston 1933	24	4	2 (50%)	20	13 (65%)
Strauß Basel 1936	*8*	*0*	*0*	*8*	*1 (12 5%)*
Szucs Leipzig 1933	70	41	22 (53 7%)	29	14 (48 3%)
Blechschmidt Bohler Vienna 1933	45	11	9 (81 8%)	34	29 (85 3%)

Twenty of the 45 cases were insured against industrial accidents Of these 19 receive no compensation One patient draws disability pay He was operated upon with poor technique by an inexperienced doctor

Forearm and Radius Fractures From 1926—1934, 718 insured forearm and radius fractures were treated These two types of fractures are taken together because they are presented thus in the statistics of 1910—1911 The results were as follows

	No of cases	Receive no compensation after 3 years	Receive permanent compensation	Death during treatment
1926—1934 treated in the Accident Hospital	718	691 (96 4%)	26 (3%)	1 (0 12%)[3]
1910/11 treated elsewhere	346	130 (37 5%)	215 (62 2%)	1 (0 3%)[1]

1 Died from another injury
2 Blechschmidt Arch klin Chir 187 1936 The other references will be found here also
3 Died from other illnesses or injuries

Closed Fractures of the Shafts of Both Bones of the Forearm Trojan[1] has reexamined our 277 fresh closed fractures of the shafts of both bones of the forearm from the years 1926—1947 Two had pseudarthroses of the radius and eight of the ulna Pseudarthroses of both bones did not occur For details see Vol I/page 771

Fractures of the Radius In the first 13 years we treated approximately 1800 fractures of the distal end of the radius By 1956 this number had risen to about 15,000 Thalt[2] has reexamined the 481 cases of the five years 1926—1930

Fingers, elbows and shoulders were freely mobile in their full range in all cases

The average time of treatment was 40 5 days Compare with example 1, page 2163

There were 172 insured industrial accidents without other injuries among the 481 reexamined cases *None received compensation* The 81 fractures of the radius of the year 1929, which were insured by the Workers Accident Insurance Co, were examined for comparison The following differences were found

Comparison between those patients from Vienna, Lower Austria and Burgenland insured by the Workers Industrial Accident Company treated (a) in the Accident Hospital and those treated (b) outside the Accident Hospital

	No of cases	Average duration of treatment in days	*No compensation at all*	Draw permanent disability pension (in %)	Working days lost	Loss in wages
In the Accident Hospital	172	40 5	24 5%	0	143 7	S 9 196
Outside the Accident Hospital	81	57	1 2/	11 1	475 7	S 30 450

The surmised lost working day is calculated in the following way Every treatment day is calculated as a whole day If a patient is awarded a compensation of for instance 50% at the end of treatment, during the time that this pension is paid, every day is calculated as a half day With 25% disability pension every day is calculated as one-fourth day

Since a worker currently (1956) earns on an average S 64 a day, those patients treated in the Accident Hospital with 143 7 lost working days have lost an average of S 9196 —, while those treated outside the Accident Hospital have lost an average of S 30,450 — The surmised loss in wages is on the average S 21 254 — less for the patients treated in the Accident Hospital than for

[1] Trojan F 277 frische geschlossene Schaftbruche beider Vorderarmknochen Hefte Unfallheilk 46 140—209

[2] Thalt W Behandlungsergebnisse der Bruche am unteren Speichenende Arch orthop Unfallchir 35 443—465 1935

	No of cases	No compensation after 3 years	Permanently disabled	Death during treatment	After conclusion of treatment receiving compensation died from another illness
1925—1934 treated in the Accident Hospital	103	85 (82%)	12 (12%)	2 (2%[1])	4 (4%)
1910/11 treated elsewhere	63	14 (22 2%)	49 (77 8%)	—	—

Olecranon Fractures In the 10 years from 1926—1935 we treated 45 fractures of the olecranon Nine of these were open Blechschmidt has reexamined these and worked out the following comparison statistics

	Reexamined cases	Not Operated	Of these good	Operated	Of these good
Madlener Bonn 1932	22	7	5 (71 4%)	15	8 (53 3%)
Daland Boston 1933	24	4	2 (50%)	20	13 (65%)
Strauß Basel 1936	8	0	0	8	1 (12 5%)
Szucs Leipzig 1933	70	41	22 (53 7%)	29	14 (48 3%)
Blechschmidt Bohler Vienna 1933	45	11	9 (81 8%)	34	29 (85 3%)

Twenty of the 45 cases were insured against industrial accidents Of these 19 receive no compensation One patient draws disability pay He was operated upon with poor *technique by an inexperienced doctor*

Forearm and Radius Fractures From 1926—1934, 718 insured forearm and radius fractures were treated These two types of fractures are taken together because they are presented thus in the statistics of 1910—1911 The results were as follows

	No of cases	Receive no compensation after 3 years	Receive permanent compensation	Death during treatment
1926—1934 treated in the Accident *Hospital*	718	691 (96 4%)	26 (3%)	1 (0 12)[3]
1910/11 treated elsewhere	346	130 (37 5%)	215 (62 2%)	1 (0 3%)[1]

1 Died from another injury
Blechschmidt Arch klin Chir 187 1936 The other references will be found here also
3 Died from other illnesses or injuries

associated injuries, six are over 58 years old I mention for comparison, that of the 73 fractures of the femur of the Workers' Accident Insurance Company of Vienna of the years 1910—1911 not less than 90 4% have received a permanent disability pension

The following table shows the average duration of treatment until resumption of heavy work, the permanent disability pensions, the working days lost and the wages lost of the 32 cases of fracture of the shaft of the femur reported to the Workers' Industrial Accident Company in Vienna of the year 1927 Of these 14 were treated in the Accident Hospital and 18 outside of the Accident Hospital I[1] have presented them not only from in front, but also from the side with the knee extended and flexed and with roentgenograms before treatment and at the time of reexamination

	Average duration treatment in days	% receiving permanent disability pension	Working days lost	Surmised loss of wages for every case
Treated in the Accident Hospital	240	10 2	627	S 40 128
Treated outside the Accident Hospital	390	22 6	1819	S 116 416

The calculation of the work days lost has shown that every one of the 14 treated in the Accident Hospital has lost an average of 627 days while every one of those treated elsewhere has lost an average of 1819 surmised work days Those treated elsewhere have then lost on an average of 1192 work days more than those, treated in the Accident Hospital If one assumes an average daily wage of S 64 —, an average loss in wages of S 40,128 — results for each of the 14 treated by us, while a surmised average loss in wages of S 116,416 — results for each of the 18 treated elsewhere The loss in wages in our 14 cases is then an average of S 76,288 — less than in those treated elsewhere In all 14 of our own cases together the loss in wages is S 1,068,032 — less than in the 18 treated elsewhere

The results of treatment can best be seen in figures 3097—3098 Figures 3094—3096 show that already in 1917, that is 40 years ago, we were able to achieve healing without significant shortening, angulation or rotation and with good mobility by suitable organization and proper methods of treatment with the simplest means and the lowest costs

The objection has often been made to me, that many of these individuals would also have become jobless without an injury, and that one cannot therefore speak of work days lost and that it would only be an advantage for the unemployment insurance if part of the workers were cared for by support from accident insurance With this concept, however, every treatment of an injured or ill person would be without purpose It is also incorrect, because every unemployed person receiving a compensation continues to receive this compensation in addition to his unemployment compensation

[1] Bohler L Behandlungsergbnisse der Oberschenchelbruche Arch orthop Unfallchir 35 466—510 1935

the patients treated outside the Accident Hospital Calculated for 172 cases this amounts to S 3,655,688 — less loss in wages for those patients treated in the Accident Hospital than for those treated elsewhere In addition to this, not a single patient of those treated in the Accident Hospital receives a permanent pension

The figures of R Watson-Jones[1] are very impressive Up to 1930 he treated fractures of the radius without splinting with massage, passive motion and hot baths The average duration of treatment was 224 days and the treatment costs for every case came to 157 English pounds After 1930 he began treatment according to our methods, namely, reduction, immobilization and active *painless* exercise without massage, without passive motion and without hot baths Since then the treatment time has decreased to 31 5 days and the treatment costs amount to only 25 English pounds

These figures indicate that the trade associations will in the next years stop requiring of every doctor that he begin massage as early as possible in cases of fractures of the radius and also all other injuries They will also probably stop spending large sums for Institutes for massage and passive motion

Fractures of the Carpal Navicular From 1926—1952 we[2] treated 734 fresh fractures of the body of the navicular Of these 580 (79%) could be followed for 1 to 26 years Of 576 usable cases, 557 (96 65%) healed by bony union, 19 (3 35%) have a pseudarthrosis In all of these it could be demonstrated that immobilization was of too short duration Of the 734 injuries 533 were insured industrial accidents without additional injuries Four (0 75%) of these receive a permanent disability pension Four further figures see Vol I/pages 877—881

Fractures of the Neck of the Femur From 1926—1931 we treated 20 adduction or varus fractures conservatively with a Whitman spica Of the 18 survivors *10 healed by bony union Stohr[3] has reexamined them For further* details see Vol II/pages 1230, 1231

The 399 adduction or varus fractures operated on by us in the years 1933—1948 were reviewed by Ender[4] He was able to reexamine 193 after 3 to 18 years 121 of 130 fresh cases operated upon healed by bony union For the other results see Vol II/pages 1340—1342

Fractures of the Femur I have treated about 1200 closed fractures of the femur in all The average shortening was 0 3 cm Of the 226 closed fractures of the shaft of the femur of the years 1926—1935, 102 were insured against accident Fourteen (13 73%) of these receive a permanent disability pension, seven because of simultaneous associated injuries Of the seven cases without

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[1] Watson Jones R Avoidable wastage in industrial injuries Liverpool Medico Chir J *41* 44 1933

[2] Böhler L Trojan E and Jahna H Behandlungsergebnisse von 734 frischen einfachen Brüchen des Kahnbeinkörpers der Hand Wiederherstellungschir Traum 2 86—111 S Karger Basel New York

[3] Stohr W 27 mediale Schenkelhalsbruche und ihre Ergebnisse bei konservative Behandlung Arch orthop Unfallchir *36* 143—178 1935

[4] Ender J Behandlung der intraartikularen Schenkelhalsbruche und ihre Folgen mit Ergebnissen der Nachuntersuchung Arch orthop Unfallchir *45* 237—253

associated injuries, six are over 58 years old *I mention for comparison, that* of the 73 fractures of the femur of the Workers' Accident Insurance Company of Vienna of the years 1910—1911 not less than 90 4% have received a permanent disability pension

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The objection has often been made to me, that many of these individuals would also have become jobless without an *injury*, and that one cannot therefore speak of work days lost, and that it would only be an advantage for the unemployment insurance if part of the workers were cared for by support from accident insurance With this concept, however, every treatment of an *injured or ill* person would be without purpose It is also *incorrect*, because every unemployed person receiving a compensation continues to receive this compensation in addition to his unemployment compensation

[1] *Bohler L Behandlungsergbnisse der Oberschenchelbruche* Arch orthop Unfallchir *35* 466—510 1935

Jorg Bohler [1 2] has reported the fractures of the shaft of the femur, treated by intramedullary nailing between the years 1941—1948 Those without associated injuries were hospitalized for 30 days as compared to those treated in traction whose hospital stay was 117 days The entire duration of treatment was 167 days as compared to 240 for those treated in traction For more details including pseudarthroses see Vol II/pages 1473—1480

Ehalt [3] has reported 23 *fresh open fractures of the femur* treated in traction and J Bohler 26 *fresh open fractures of the femur* treated by intramedullary nailing All of the 23 treated in traction healed without infection and only one of those treated by intramedullary nailing developed a minor infection For more detail see Vol II/pages 1477 and 1480

I have reported the results in *gunshot fractures of the femur* in Vol I/pages 199—203, 280 The results of Jimeno Vidal and Wustmann are presented in Vol II/page 1502

Patella Fractures H R Schonbauer has collected the 574 patients with 578 fractures of the patella treated in the years 1926—1952 330 of these could be reexamined after an observation time of 2—24 years The results are described on pages 1539—1542

Fractures of the Proximal End of the Tibia Ender [4] has collected the 305 fractures of the proximal end of the tibia treated by us between the years 1925—1948 He was able to reexamine 122 of the survivors that could still be found after a period of observation of 2 to 23 years The results are described on pages 1679—1682

Closed Fractures of the Shafts of the Tibia and Fibula Ender Krotschek and Jahna [5] have reexamined our 1130 fresh closed fractures of the tibio fibular shafts from the years 1925—1950 after 2 to 23 years 554 of these (49 33%) were insured industrial accidents 55 (9 93%) draw permanent dis ability pensions Of these 55 34 were more than 50 years old For further details see pages 1764—1769

Open Fractures of the Shafts of the Tibia and Fibula In the 25 years from 1925—1950 we have treated 506 fresh open fractures of the shafts of the tibia and fibula They have been reviewed by Ehalt [6], Zrubecky , and Krosl [8]

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1 Bohler J Results in medullary nailing of ninety five fresh fractures of the femur J Bone Joint Surg *33 A* 670—678 1951

Bohler J Behandlungsergebnisse bei 151 Marknagelungen des Oberschenkels Hefte Unfallheilk *46* 6—93 1953

3 Ehalt W Behandlung der offenen Bruche der langen Rohrenknochen Vienna Verlag Maudrich *1938*

4 Ender J Behandlung und Behandlungsergebnisse der Schienbeinkopfbruche Arch orthop Unfall chir *47* 130—145 1955

5 Ender J Krotschek H and Jahna H Behandlung und Behandlungsergebnisse von 1130 frischen geschlossenen Unterschenkelschaftbruchen Hefte Unfallheilk *54* 14—92 1957

6 Ehalt W Behandlung der offenen Bruche der langen Rohrenknochen Vienna Verlag Maudrich 1938

7 Zrubecky G Behandlung und Behandlungsergebnisse von 461 frischen offenen Unter schenkelschaftbruchen Hefte Unfallheilk *54* 93—180 1957

8 Krosl W Ergebnisse der Marknagelung bei 65 geschlossenen und 45 offenen Bruchen des Unterschenkels Hefte Unfallheilk *54* 181—206

Old Fractures of the Shafts of the Tibia and Fibula Jahna and Scharizer[1] have reexamined 1432 old fractures of the shafts of the tibia and fibula treated by us and calculated how much money could have been saved if these patients had been brought to us in time

Gunshot Fractures of the Lower Leg I have reported the results in Vol I/pages 199—203 and 280 The results of Jimeno Vidal are presented on page 1887

Fractures of the Calcaneus In the ten years between 1926—1935 we treated 228 patients with 247 fresh fractures of the calcaneus 180 of the 228 cases were covered by industrial accident insurance Of these 8 receive permanent disability pension These cases were reexamined by Gollasch[2] The results are presented on pages 2108—2114

Dislocations Shoulder Dislocations In the seven years between 1926 to 1932, 116 dislocations of the shoulder were treated This number has now increased to over 1800, 54 of the first 116 were insured against accidents According to the reexaminations by Biebl[3] only 2 patients receive a permanent pension For details see Vol I/ pp 572, 573

Dislocations of the Elbow[4] In the ten years between 1926—1935 we have treated 51 dislocations of the elbow Their number has now increased to over 600 21 of the first 51 were insured against accident Only one patient is drawing a permanent disability pension

Of the 28 pure dislocations 27 have full flexion and extension and only a single case has 5° limitation of extension For more details see Vol I/pages 701, 702

Dislocations of the Head of the Radius with Fracture of the Ulna Leitner[5] has reexamined the 27 fresh cases treated by us in the 22 years between 1926 to 1948 and has found good results in most of these For more details see Vol I/pp 719, 720

Dislocations of the Lunate In the 12 years between 1926—1937 we have treated 36 pure dislocations of the lunate and 14 dislocations of the lunate associated with fractures of the navicular In the meantime this number has increased to more than 200 According to the review by Perschl[6] 20 of the 36 cases of pure dislocation of the lunate were without associated injuries None draw pensions Among the 14 dislocations of the lunate with fracture of the

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[1] Jahna H and Scharizer E Kritik der Behandlungsergebnisse bei 1432 von 1926—1950 veraltet in das Unfallkrankenhaus Wien eingelieferten geschlossenen und offenen Unterschenkelschaftbruchen Heft Unfallheilk *54* 207—227 1957

[2] Gollasch W Behandlungsergebnisse von 250 Fersenbeinbruchen Hefte Unfallheilk *31* 1—163 1941

[3] Biebl R Behandlung und Prognose frischer Schulterluxationen Arch orthop Unfallchir *35* 381—396 1935

[4] Biebl R Über Endausgange traumatischer Verrenkungen und Verrenkungsbruche des Ellbogengelenkes Arch orthop Unfallchir *37* 55—73 1936

[5] Leitner Baldo Behandlungsergebnisse der Bruche der Elle mit begleitender Speichenkopfchenverrenkung (Monteggia Verletzung) Hefte Unfallheilk *46* 102—139 1953

[6] Perschl A Behandlung und Behandlungsergebnisse perilunarer dorsaler Verrenkungen und der Verrenkungen des Mondbeines nach volar Ergebn Chir Orthop *35* 437—517 1949

navicular 11 were insured Of these, one receives a permanent disability pension For more details se Vol I/pages 849—851

Dislocations of the Hip Obwegeser[1] has reexamined the dislocations of the hip that were treated by us in the 6 years from 1929—1934 Scheel in 1942 examined the 25 cases that had been treated by us between 1929 and 1939 In 1954 the 79 dislocations of the hip that were treated between 1929—1934 were reviewed by Trojan[3] and Perschl Their number has now increased to 137 The results of these investigations show that pure dislocations of the hip have a very good prognosis if they are reduced on the first day and not treated by massage, passive motion, overheating and overcooling For more details see Vol II/pages 1127—1129

Central Dislocations of the Hip The 57 central dislocations of the hip from the years 1926—1951 were reexamined by Wechselberger[4] For more information see Vol II/pages 1139—1143

Dislocation of the Knee Kromer[5] in 1936 reexamined our first 10 cases from the years 1927—1934 and Ender reexamined the 22 cases from the years 1935—1947 More an pages 1560—1562

Meniscus Injuries Between 1926 and 1953 we opened 1078 knee joints because of suspicion of a meniscus injury In 1012 cases (93 87%) we found a tear of the meniscus Kromer[6] reexamined our first 111 cases from the years 1926 to 1933 Then Benkovitch examined the 189 cases from the years 1934 to 1939 and Streli[7] in 1951 the 834 cases from the years 1926—1949 Of the first 57 insured patients only one draws a permanent disability pension For more details see pages 1615—1620

Subtalar Dislocations of the Foot Leitner[8] has reviewed the fresh cases treated by us in the 25 years from 1926—1950 He was able to reexamine 37 of the 42 cases Their number has increased by now to 78 In pure dislocations the results were always good In those with chip fractures disturbances of mobility remained For more details see pages 2043—2045

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1 Obwegeser Symptome Behandlung und Prognose frischer traumatischer Huftverrenkungen Arch f orthop u Unfall Chir *37* 80—106 1936

Scheel Dissertation 1942

3 Trojan und Perschl 1956 Behandlungsergebnisse von 79 frischen traumatischen Huftgelenkverrenkungen (H V) und Huftgelenkverrenkungsbruchen Ergebn Chir Orthop *40* 90—164

4 Wechselberger Erfahrungen und Behandlungsergebnisse an 57 frischen Huftpfannenbruchen mit zentraler Luxation des Oberschenkelkopfes Ergebn Chir Orthop *40* 224—265 1956

5 Kromer Behandlung und Ergebnisse der traumatischen Kniegelenksverrenkungen Ergebn Chir Orthop *29* 583—626 1936

6 Kromer K Meniscusoperation und Unfallversicherung Arch f orthop u Unfall Chir *35* 1935

7 Streli R Spatergebnisse nach partieller Meniscusoperation bei *82 Fallen welche 18—25* Jahre nach der Operation nachuntersucht wurden Der Chirurg *26* 97—103 1955

8 Leitner *Baldo* Behandlung und Behandlungsergebnisse von 42 frischen Fallen von Luxatio pedis sub talo im Unfallkrankenhaus Wien in den Jahren 1925—1950 Ergebn Chir Orthop *37* 501—577 1952

Total dislocation of the talus was also reviewed by Leitner[1], see pages 2026 to 2033

Gunshot Injuries of Joints My results in the cases of *gunshot injuries of the shoulder joints* are described in Vol I/pages 198—201 and those of Jimeno Vidal in Vol I/page 617

Gunshot Injuries of the Elbow Joint My cases are described in Vol I/pages 198—201 and those of Jimeno Vidal in Vol I/page 728

Gunshot Injuries of the Wrist Joint Jimeno Vidal's results are given in Vol I/page 891

Gunshot Injuries of the Hip Joint My cases are described in Vol I/pages 198—201 and those of Jimeno Vidal in Vol II/page 1158

Gunshot Injuries of the Knee Joint My results are given in Vol I/pages 198—201 and those of Jimeno Vidal on page 1638

Gunshot Injuries of the Ankle Joint My results are given in Vol I/pages 198—201 and those of Jimeno Vidal on pages 2133 and 2135

VIII OPERATION COSTS AND MATERIAL USED

From January 1 until December 31, 1955 the following number of patients were treated

In the Accident Hospital	4,527
In the Outpatient Department	55,861

Most of those treated as in-patients were treated further as outpatients

The average duration of treatment in the Accident Hospital was 12 34 days and in the outpatient department 13 3 days The duration of treatment in the hospital is so short, because the patient had to be discharged early due to lack of room

Most of the patients were treated until healed and were only rarely transferred to another institution, for instance because of internal diseases

In 1955, 13,338 open operations were carried out The majority of these were wound excisions with and without closure by suture In addition numerous hip nailings, intramedullary nailings, operations for non-union, arthrodeses, tendon and skin grafts and other operations were carried out (see p 2256)

The total cost of operating the Accident Hospital and the Outpatient Department was S 9,645,809 (DM 1,607,635, U S $ 370 992) This was distributed as follows

1 Personnel (Doctors Nurses Attendants and Kitchen help)		S 6 145 290 (63 7%)
2 Materials		S 2 171 776 (22 5%)
Kitchen	S 659 664 (6 8%)	
Drugs	S 344 787 (3 6%)	
Instruments Dressing etc	S 576 533 (5 9%)	
3 Utilities (heating light laundry painting and janitor)		S 1 328 147 (13 8%)

In 55,875 nursing days S 206,872 were spent for drugs for the 4527 *inpatients*

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[1] Leitner Baldo Die Totalluxation des Talus und ihre Vorstufen Ergebn Chir Orthop *38* 95—135 1953

		Average duration of treatment	Cost per case	Cost per day
Drugs	S 206 872	12 34	S 45 70	S 3 70
Penicillin and other antibiotics	S 76 834	12 34	S 16 99	S 1 37
Tetanus antitoxin	S 12 545	12 34	S 2 77	

S 137 915 were spent for drugs in 711 164 patient days for 55 861 out-patients

		Average duration of treatmen	Cost per case	Cost per day
For drugs	S 137 915	13 3	S 2 59	S 0 20
For penicillin and other antibiotics	S 19 211	13 3	S 0 34	S 0 02
For tetanus antitoxin	S 50 180	13 3	S 0 86	—

The amount of antibiotics used is so small because as a rule they are not used in those cases in which early and thorough wound excision can be carried out We use them most for the numerous cases which come to us with tendon sheath infections and are incised

In our rehabilitation center, Stollhof,' (see p 2246) we use very few drugs In 1955 S 2,849 53 were spent in 32 639 patient days for 1081 patients

		Average duration of treatment in day	Cost per case	Cost per day
For drugs	S 2 849 53	S 31 2	S 2 64	S 0 09

I believe that the patients there look so well because they get so few drugs and receive instead *painless* exercises and good food Most of them gain considerable weight

In comparison I would like to mention that in my military hospital for gunshot fractures and gunshot injuries of joints in Bozen from 1916—1918 I also used very few drugs and dressings

I[1] have presented an accurate record about these at the Deutsche Orthopadenkongreß of 1923 on page 260 Because at that time I received very little material for dressings I began to make non-padded casts and to treat the wounds exposed I later discovered that Kern had used exposed treatment of wounds already in the Napoleonic wars

Besides there is a general complaint about the increased use of drugs The Austrian National Health Insurance covering 2 6 million insured persons spent 2 615 million shillings in 1955 Of this sum 400 million shillings were used for drugs

The Vienna National Health Insurance with 866 838 insured persons had a total expenditure of S 667 million in 1955 Of this amount 106 million (15 8%) were used for drugs 426 589 of the 866 838 insured namely every other one, reported sick in 1955 8,736 952 prescriptions were written representing an average of 10 prescriptions or S 131 34 per *insured* individual or

1 Bohler L Wie schutzen wir die Verwundeten vor Amputationen und Kruppeltum? Ztschr Orthop Chir 45 244—281, 1924

double that amount per individual reported sick These were chiefly persons treated as outpatients The drugs used for the severely ill who were admitted to hospitals are not considered here

S 106 million were spent by the Vienna National Health Insurance in 9 384 958 patient days for the 426 589 persons reported sick

		Average time of illness in day	Cost per case	per day
For drugs	S 106 000 000	22	S 262 —	S 11 9

The comparison of the expenditure for drugs for the outpatients of the old Vienna Accident Hospital with that for the out patients of the Vienna National Health Insurance seems to me quite interesting

IX RESEARCH IN THE ACCIDENT HOSPITAL

In order to be informed about the literature the Accident Hospital before the war took 32 publications in seven languages At the present time there are only 21 in five languages In addition I own all of the newer and most of the older books from this and the past century about the treatment of fractures and disability evaluation as well as numerous works about wound treatment and general surgery which are available to the doctors of the Accident Hospital

The problems are clear We attempt to clarify the mechanism, diagnosis treatment and disability evaluation of shock, hemorrhage, fat embolism, posttraumatic pneumonia, thrombosis and embolism, wound infection and wound healing of decubitus ulcers, injuries of the central and peripheral nervous system, fractures and dislocations as well as their complications The cause prevention and treatment of disturbed callus formation (delayed or absent callus formation) disturbances in circulation (acute and chronic ischemia, edema and cyanosis), disturbances of mobility through changes in the cartilage capsule and ligaments of muscles and tendons, of myositis ossificans, then of muscle atrophy as well as late arthroses and necroses, should be further examined Most of these disturbances may be attributed to changes in innervation of vessels as a result of the pain stimulus

The influence of pain on the blood vessel innervation leads to the problem of psychosomatics Here the influences of the environment (fact of being insured, party politics, etc) on the traumatic neurosis should not be overlooked Only by clarification of all of the circumstances presented can the results of treatment be improved

Our researches are carried out primarily at the bedside and less in the laboratory The majority of these problems cannot be solved by animal experiments or with the microscope, but only by accurate observation of the patient I sometimes have the impression that bedside observation recedes too much into the background and that the records which should be made at the initial examination, further treatment, at the close of treatment and at reexamination and disability evaluation are not always adequate

Statistics Among the most important tools for research in many obscure occurrences and conditions and for final proof that the results of laboratory researches were correct, are accurate statistics that are developed on the basis of *exact facts* The number of cases described should be adequate and the observation time long enough and as a rule should not extend over months, but rather over years and decades The researcher must have enough experience to develop his work according to a plan, in order that comparison with other publications is possible *It is especially valuable if, in the case of insured individuals, the* disability compensations are also indicated, because in questionable cases they are the result arrived at by various examiners and because every patient who is not satisfied with his estimate of disability can appeal his case

Comparison with other publications is often quite difficult because often various types of injuries and various stages of injuries are lumped together, and no distinction is made between fresh and old, open and closed, uninfected and infected fractures, young or old patients, etc In order to arrive at valid results suitable classification is necessary

Plan for Follow-up Examinations The individual patients are classified according to age, pathological changes, duration of treatment and prognosis, in order to determine what circumstances have influenced the results of treatment, which patients have completely healed, and which ones had temporary or permanent complications and which ones died

Then the numbers of the injured and the results are compared with those of all others published in the accessible world literature

Finally the results are evaluated in order to discover the apparently best methods of treatment

We approach this problem in the following manner

1 Looking up the name X-ray number and date from the continuous admission, operation and X-ray protocols
2 Looking up the admission number In the case of inpatients in the admission office and in outpatients in the registry of names in the Outpatient Department *At the same time recording the age occupation and* address
3 Looking up the outpatient records and the medical records
4 Looking up the roentgenograms from the X-ray files
5 Looking up the photographs from the photograph files
6 Recording the cases in the follow-up examination forms after previously dividing them into certain groups As example see Vol I/pages 694 1052—1072
7 Abstracting the findings from the literature on separate sheets It is best to begin with the Zentralorgan f d ges Chirurgie and then look up the remaining literature in the *Index Medicus* and read it
8 Make out a notebook or loose leaves A separate page is used for each question, for instance for age distribution deaths, operative treatment etc, (as example see Bohler Die Marknagelung nach Kuntscher, fifth

to eleventh editions, pages 1601—1613) The fractures of the patella that have been reviewed by H Schonbauer [1] are presented here as example

9 Reading of the literature and entering of pertinent comments with names of the author, the clinic, the journal, the year, the volume number and the pages indicated under 8 above

10 Also read the pertinent works of surgery and accident surgery

11 Before beginning the examinations again discussion with the Chief regarding what points shall be looked for, which roentgenograms and photos shall be made and who shall pay the transportation costs

12 The progress of the work should be reported to the Chief every two months Since 1952 we have changed over to recording all of the findings of the follow up examination on IBM cards As a result, the evaluations are more easily carried out and are more accurate

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[1] *Example* Fractures of the patella are reviewed from the following viewpoints

Viewpoints alphabetically

After treatment
Age
Amputations
Arthroses
Associated injuries
Conservative treatment
Death
Diagnosis
Disability evaluation
Duration of treatment
Empyema of the knee joint
Extirpation
Fresh closed fractures
Fresh open fractures
Incidence
Increased likelihood of fracture
Infected fractures
Location and form of fracture
Mechanism of accident
Myositis ossificans
Number of cases
Old fractures
Onset of treatment
Operative methods
Pensions
Pseudarthroses
Quadriceps plasty
Refractures and secondary fractures
Results of treatment
Sex
Side
Stiffness of the knee
Type of fixation — duration
Type of treatment

Viewpoints systematically

Number of fresh open fractures
— of fresh closed fractures
— of old fractures
— of infected fractures
— of pseudarthroses
Age
Sex
Side
Mechanism
Diagnosis
Incidence
Increased susceptibility to fractures
Secondary fractures
Refractures
Type of treatment conservative
— operative
— extirpation
Treatment with massage and passive motion
— — splints
— — plaster
— — quadriceps plastic
Duration of immobilization
— of entire treatment
— of hospitalization
— of ambulatory treatment
Results of treatment
Death
Amputations
Empyema of the knee joint
Stiffness of the knee joint
Arthroses
Function
Myositis ossificans
Disability evaluation
Pensions

Fracture Protocols Since 1916 in order to maintain an accurate survey over my entire material I have classified all fractures and dislocations treated by me according to segments of limbs, gathered together in separate protocols in which everything worthy of note is recorded Every case is entered in these so that none can be lost I have preferred these protocol books to the medical records in this matter, because their preservation and maintenance is more certain Since 1957 we have made out an IBM card for each patient

In addition we maintain separate protocols arranged according to segments of limbs for osteosynthesis, pseudarthroses, arthrodeses, nerve suture, tendon suture, etc

On the last page of the operation protocols the number of all-important operations is separately recorded so that they can be found at any time and assembled

Every month a so-called per secundam list is made out in order to keep a check on the results of the operative treatment In this list are recorded the diagnosis, the operation the age, the occupation of the patient and the name of the doctor of those patients who did not heal p p (per primam)

At the end of every year all deaths are summarized, in order to determine what could have been undertaken in order to prevent them Their number has materially decreased as a result of modern anti-shock treatment, blood banks and antibiotics

I have been able to keep intact the entire material from the first World War (fractures, operation protocols, register of names, roentgenograms — on glass plates and photographs) in spite of two world wars, several political upheavals, and several moves Unfortunately the records roentgenograms, etc from the second World War were largely lost On the other hand all fracture and roentgen protocols, roentgenograms, photographs and lantern slides in the Accident Hospital which at the end of the war lay in the front line on the shore of the Danube canal were preserved in spite of direct shelling The only things missing are the operation protocols from the years 1926—1938 that fell prey at that time to a misguided clean up If we had had only loose cards many would probably have been lost

In the 31 years from December 1 1925 to December 31, 1956 three quarters of a million patients have been treated in the Vienna Accident Hospital, namely 90,078 inpatients and 655,950 outpatients Roentgenograms were made for 286,000 patients More than 2,500 000 films are stored in the roentgen files

Since the administration of the General Accident Insurance Company and the Accident Hospital are housed in the same building, there is relatively easy access to the compensation files in order to be able to also carry out the pertinent investigations in this direction

Currently the Accident Hospital is in possession of the largest series of cases in the world literature of most types of injuries A large number with long term follow-up up to 30 years have already been published Many previously unknown conclusions could be reached thereby and the treatment could be improved Thus the Vienna Accident Hospital with its great collec-

tions is at present the greatest research institute in the world in the field of accident surgery

In the follow up examinations I place especial value on as large numbers of cases as possible that have been observed over long periods of time Only thus can one learn which methods of treatment yield the best results In order to evaluate the individual cases as accurately as possible we have utilized the IBM card system (punch card system) since 1952 For instance, we have re-examined 400 fractures of the neck of the femur, 560 fractures of the patella, 700 fractures of the navicular of the hand, and more than 3000 fractures of the lower leg using this system The figures thus obtained were evaluated by the Institute for Statistics of the University of Vienna

The following can be listed as resulting from this research New methods of treatment of injuries of the carpus, of fractures of the neck of the femur, of the calcaneus of the forearm, and of the vertebrae and of various dislocations, avoidance of most pension neuroses avoidance of myositis ossificans and simplification of wound treatment

There are men of great influence, who express themselves as being against the founding of any more research institutions as they are envisioned on page 2297 They fear that the injured workmen would there be used as guinea pigs One cannot level this criticism at the Vienna Accident Hospital, since no patient has suffered from the fact that his medical record and roentgenograms have been reviewed and that he was asked to appear for reexamination after 10 20 or 30 years Not even a single mouse, rabbit or dog has been used for an experiment

X TEACHING IN THE ACCIDENT HOSPITAL

I began with my wild teaching activity already during World War I in spite of much opposition Approximately 400 Austrian and German doctors came to my military hospital for gunshot fractures and joint injuries and about 40 Italians during my military captivity

The Accident Hospital in Vienna was visited since 1927, before World War II by approximately 300 to 700 foreign doctors annually These usually remained one to six weeks and sometimes even longer The American Medical Association of Vienna, which at that time had 200 to 300 members, arranged several courses in the Accident Hospital Sometimes two and even three were held in one day, not only by me but especially by Schneck, Ehalt and Kromer The lists of guests on pages 2290—2292 show the number of the surgeons from all parts of the globe and the scope of the teaching for doctors The number of visitors decreased from 1932—1934 because of money exchange difficulties and because of the world economic crisis, to rise again in spite of these difficulties They could participate in all procedures in the operating rooms the roentgen department, the wards and the outpatient department For this privilege they paid RM 10 — a week Books and teaching aids were bought with the income from these fees Other funds for research and teaching were not available

Teaching Films Since all types of injuries in every stage of treatment could not be shown at all times, I took motion pictures of all typical fractures and dislocations and many operations In these the clinical manifestations, the entire treatment from the first to the final result can be seen I showed these films in the Deutsche Chirurgenkongresse in Berlin in 1927, 1928, 1929, 1932 and 1953 and in the Deutsche Orthopadenkongresse 1930, 1932 and 1953 Thereupon after the surgeons of America, Asia, Africa and Australia many also came from Germany, Switzerland, Holland, Italy and especially from the nordic countries, Sweden, Norway and Denmark I learned about the methods of treatment and the organization in those countries from personal discussions Invitations followed to lecture in Czechoslovakia, Holland, Switzerland Hungary, America, England, Sweden, Norway, Denmark, Belgium, Italy and France Thus I had the opportunity to see personally the clinics and hospitals, the teaching and treatment methods and the insurance system and to come into personal contact with those men whom I had known for years from their writings and to again learn from them I now repeatedly use these films for instruction and copies of them are being shown in various clinics in North and South America, in England, Sweden, Bulgaria, Russia, South Africa, India and Australia In addition, more than 5000 slides, a large number of wall charts and models are available to me for teaching

Since 1930 I have had the opportunity to give lectures to students

The following five large wall charts are displaced in my lecture hall

I *Fundamentals of Fracture Treatment*

1 **Reduction** *In every fracture the fragments must be well reduced*

2 **Immobilization** *The reduced fragments must be* **uninterruptedly** *immobilized in good position* **with particular attention** *to the* **circulation,** *until they have reunited by bony union*

3 **Exercise** *During the necessary period of immobilization of the well reduced fragments, as many as possible or all joints of the injured limb and the entire body should be* **actively** *moved through their full range* **avoiding pain,** *in order to avoid circulatory disturbances muscle and bone atrophy and stiffening of the joints*

II *Who heals the fractured bone?*

The organism itself or nature
What does nature require for healing?

Time

What must the doctor do during this time?
After the reduction he must provide uninterrupted **rest** *for the fracture*
By instruction for active use of the injured limb and the entire body he must assure good **circulation** *while* **avoiding pain**

III *Who heals wounds?*

The organism itself or nature

What does nature require for healing?

Time

What must the doctor do during this time?

He must after primary, painstaking wound excision and suture of the skin in fresh wounds, or after accurate opening of collections of pus in infected wounds, provide for uninterrupted

Rest

and at the same time by elevation and active exercise of all portions of the body that are not immobilized provide for good

circulation, while

avoiding pain

IV Massage *and* passive motion *produce the greatest harm in the treatment of all fresh bone and joint injuries and of most old bone and joint injuries*

V The production of a proper amount of shortening is the most important problem of fracture treatment, *because necrosis of from 1—3 mm occurs after every fracture due to tear of blood vessels We must afford the fragments opportunity to come together We must therefore strive for shortening of 1—10 mm after a fracture and under no circumstances for a lengthening This sounds surprising because we have up to now always been urged to avoid any shortening However, this shortening we strive for should as a rule not amount to more than 10 mm*

The entire two hour lecture takes place on the basis of these five wall charts that contain all the fundamentals for accident surgery

Using these I attempted to warn the students from damaging overtreatment

I discuss the general fundamentals first aid and shock treatment as well as the economic significance of accident surgery in the first lecture Then I show a radius fracture or a malleolar fracture and discuss the mechanism of production, diagnosis and treatment, perform the reduction and mention the aftertreatment and the disability evaluation according to the legal provisions

In all subsequent lectures the patient who had the reduction or treatment in the previous lecture is shown first, and then every 2—3 weeks cases that had been treated previously during the lecture, until they are again able to work At the end of the semester those that have been healed for some time are presented and interviewed regarding their ability to work their earnings and their intervening fate In addition in every lecture other patients are presented who fit in the same or a related category for discussion of the differential diagnosis The mechanism of origin, diagnosis, treatment and disability evaluation are illustrated by anatomical specimens, drawings, models and roentgenograms To promote a better understanding the pertinent motion pictures are shown On these the events that take place over a period of weeks and months are shown in the course of 10 minutes From these films the treatment can be visualized more clearly than from reality

In every lecture four or five cases are also shown, in which healing has not been satisfactory as a result of various unfavorable circumstances, for instance with shortening, angulation, rotation, pseudarthroses, stiffening, infection, ischemia, etc The errors and their influence on the duration of treatment and the fate of the patients and their families are discussed, but never in the presence of the patient During this time I repeatedly refer to the five wall charts

Guest List from 1931—1943

	1931	1932	1933	1934	1935	1936	1937	1938	1939	1940	1941	1942	1943
Africa	7	4	3	2	2	11	13	6	6	—	—	—	1
Egypt	—	—	—	—	—	1	2	1	1	—	—	—	—
Albania	—	—	—	1	—	—	—	—	—	—	—	—	—
Arabia	—	—	—	—	1	—	—	—	—	—	—	—	—
Australia	4	8	8	8	15	16	29	5	1	—	—	—	—
Belgium	2	—	2	2	6	7	3	—	3	1	2	1	1
Bulgaria	1	3	1	4	2	1	6	1	2	3	5	6	1
Chile	—	—	—	—	1	7	7	—	12	—	—	—	—
China	3	—	1	4	—	4	3	4	—	—	—	—	1
Denmark	17	5	3	6	8	8	29	11	2	—	—	—	—
Germany	45	36	16	3	7	9	26	68	55	85	85	72	64
England	18	18	21	47	57	97	99	38	8	—	—	—	—
Estonia	—	—	—	1	—	1	1	3	3	—	—	—	—
Finland	3	1	—	—	—	1	1	—	3	—	—	—	—
France	9	4	6	4	10	12	7	3	4	—	—	—	—
Greece	3	—	—	3	2	9	7	4	6	—	1	3	3
Hawaii	—	—	1	—	2	2	3	1	1	—	—	—	—
Holland	7	5	1	6	8	8	10	10	1	1	—	—	3
Honduras	—	—	2	—	—	—	—	—	—	—	—	—	—
India	17	13	15	17	24	39	44	37	11	1	—	—	—
Ireland	8	—	2	8	3	6	13	4	1	—	—	—	—
Iceland	2	—	—	—	—	2	—	—	1	—	—	—	—
Italy	5	15	14	11	16	17	15	8	7	1	6	—	2
Japan	2	1	3	6	2	5	6	2	1	7	1	2	—
Java	1	1	2	—	3	2	7	—	—	—	—	—	—
Jugoslavia	4	1	3	3	5	7	4	5	3	—	—	—	—
Korea	—	—	—	1	—	—	—	—	—	—	—	—	—
Latvia	1	—	3	—	5	5	8	3	1	1	1	—	3
Lithuania	—	—	—	1	1	3	6	5	2	—	—	—	1
Luxemburg	—	—	—	2	—	—	—	1	—	—	—	—	1
Manchuria	—	—	—	—	1	—	—	—	—	—	—	—	—
Mexico	—	—	1	—	—	1	3	5	4	—	—	—	—
Middle America	2	6	—	—	5	2	2	1	8	—	—	—	—
Newfoundland	—	—	1	—	—	—	—	—	—	—	—	—	—
New Zealand	4	2	—	—	—	5	4	—	—	—	—	—	—
Norway	5	6	3	6	4	5	6	3	4	—	13	—	—
Austria	41	43	33	75	59	80	93	81	60	144	67	129	77
Palestine	—	1	—	—	1	1	6	—	—	—	—	—	—
Persia	—	—	—	1	1	2	2	3	2	—	—	—	—
Philippines	—	—	4	—	2	1	3	—	—	—	—	—	—
Poland	9	12	9	8	13	18	13	5	1	—	2	—	14
Portugal	—	—	—	—	1	3	—	1	3	—	—	—	—
Rumania	6	5	2	9	5	4	14	6	3	1	5	7	9
Russia	—	1	1	1	2	3	1	—	1	—	—	—	77

	1931	1932	1933	1934	1935	1936	1937	1938	1939	1940	1941	1942	1943
Sweden	15	8	2	3	—	4	9	6	2	—	—	—	—
Switzerland	13	13	24	13	31	28	28	6	6	1	1	2	1
Siam	—	—	—	—	—	1	1	1	3	1	—	—	—
Spain	8	10	14	10	11	6	—	—	1	1	4	11	10
South America	23	6	7	16	11	17	21	13	47	—	—	—	1
Syria	—	—	—	—	3	—	—	1	—	—	—	—	—
Czechoslovakia	12	16	11	4	14	13	8	2	—	7	4	9	5
Turkey	6	1	1	1	1	—	2	1	—	—	—	—	1
Hungary	3	7	6	5	7	4	14	6	8	2	2	4	1
U.S.A. and Canada	102	107	106	67	90	118	162	96	17	—	—	—	—
	406	354	334	357	451	604	749	465	305	257	199	246	277

Guest List from 1944—1956

	1944	1945	1946	1947	1948	1949	1950	1951	1952	1953	1954	1955	1956
Africa	—	—	—	—	—	—	—	—	1	—	—	2	3
Egypt	—	—	—	—	—	—	—	2	1	2	3	2	9
Australia	—	1	—	—	—	1	5	1	4	—	4	1	—
Belgium	1	—	2	—	—	1	1	3	4	2	3	5	3
Bulgaria	2	—	—	—	1	3	—	—	—	—	—	—	—
Chile	—	—	—	—	—	1	—	—	—	—	1	—	—
China	—	—	—	—	—	1	1	—	—	—	—	—	1
Denmark	—	—	—	—	—	—	—	—	—	—	—	—	1
Germany	210	10	1	1	1	1	1	14	8	15	40	18	38
England	—	3	11	7	2	1	2	1	2	2	2	3	1
Finland	—	—	—	—	—	—	2	—	1	—	1	1	—
France	—	1	12	2	4	4	4	9	17	3	9	24	7
Greece	1	1	—	—	—	—	1	—	3	1	3	4	3
Hawaii	—	—	—	—	—	—	—	—	—	—	1	—	—
Holland	3	—	—	—	2	—	—	2	4	2	—	2	2
India	—	—	—	—	—	1	2	1	1	8	8	3	5
Indonesia	—	—	—	—	—	—	—	2	—	—	—	—	—
Ireland	—	—	1	1	—	—	—	2	1	—	—	—	1
Italy	1	—	1	—	—	6	6	24	35	17	25	15	10
Japan	1	—	—	—	—	—	—	—	—	—	2	2	—
Java	—	—	—	—	—	—	—	—	—	—	—	1	—
Jugoslavia	5	1	1	1	—	—	2	4	2	4	7	7	5
Lebanon	—	—	—	—	—	—	1	1	—	1	—	—	—
Lithuania	8	—	—	—	—	—	—	—	—	—	—	—	—
Luxemburg	1	—	—	—	—	—	—	—	—	—	—	—	—
Madagascar	—	—	—	—	1	—	—	—	—	—	—	—	—
Mexico	—	—	—	—	—	—	—	—	1	—	3	2	—
Central America	—	—	—	—	—	—	—	—	2	—	5	2	—
Norway	—	—	—	—	—	—	2	—	—	—	—	—	1
Austria	119	37	42	23	56	54	43	116	70	48	26	39	23
Palestine	—	1	1	—	—	—	—	—	—	1	1	2	1
Persia	—	—	—	—	—	—	—	—	—	—	1	2	—
Philippines	—	—	—	—	—	—	—	—	—	1	1	—	—
Poland	6	6	2	3	2	—	—	—	—	—	2	2	3
Portugal	—	—	—	—	—	—	—	—	2	—	1	1	—
Rumania	6	—	—	—	—	—	—	1	—	—	—	—	—
Russia	2	237	139	—	—	—	1	—	—	2	—	2	—
Scotland	—	—	2	—	—	—	—	—	1	—	1	1	—
Sweden	1	—	—	—	—	2	1	3	—	3	2	1	1
Switzerland	1	—	—	—	1	6	9	11	12	8	5	12	38

	1944	1945	1946	1947	1948	1949	1950	1951	1952	1953	1954	1955	1956
Siam	1	—	—	—	—	—	—	—	1	2	—	—	—
Spain	2	—	—	—	—	—	6	8	4	1	7	3	4
South America	—	—	—	—	—	2	4	15	9	5	13	11	5
Sumatra	—	—	—	—	—	—	1	—	—	—	—	—	—
Czechoslovakia	19	2	1	—	—	—	—	—	—	—	—	—	1
Turkey	1	—	—	—	—	1	1	2	—	3	1	2	2
Hungary	5	3	1	2	1	1	—	—	—	—	—	—	6
U S A and Canada	1	5	6	6	14	28	12	13	16	16	20	30	14
	388	308	223	47	85	114	108	235	202	147	197	202	188

The guest lists give an interesting picture of the political world conditions and show, that individual countries isolate themselves The currency valuations also played an important role When the currency value fell, immediately the number of guests from that country decreased After the second world war the number of guests decreased because they wished to avoid the occupation forces

Books and Scientific Publications Appearing from the Accident Hospital

Sixteen books have appeared from the Accident Hospital Of these some have appeared in numerous German editions and editions in other languages, besides 742 scientific publications

Books

I Lorenz Bohler Die Technik der Knochenbruchbehandlung Vienna Maudrich The following editions have appeared 13 German 5 English 4 Spanish 2 Russian 2 French 2 Italian and 2 Polish

II Bohler Jeschke Operative Behandlung der Schenkelhalsbruche und Schenkelhalspseudarthrosen und ihre Ergebnisse Vienna Maudrich
1 German edition 1948 1 Spanish edition 1940

III Bohler Die Marknagelung nach Kuntscher Vienna Maudrich
1—4 German edition January 1944
5—8 German edition September 1944
9—11 German edition 1945
1 English edition 1948
1 Italian edition 1951
1 Spanish edition 1952

IV Bohler Verbandslehre fur Schwestern Helfer Studenten und Arzte Vienna Maudrich
1 German edition 1947
1 Turkish edition 1948
1 Chinese edition 1949
1 Portuguese edition 1950
2 Chinese edition 1950
1 Dutch edition 1950
3 Chinese edition 1951
1 Jugoslavic edition 1951
1 Italian edition 1951
1 Spanish edition 1953

V Bohler Unfallchirurgie in Therapie und Praxis Vienna Urban and Schwarzenberg
1 Edition 1948
2 Edition 1952
3 Edition 1957

Unfallchirurgie in Konsilium Vienna Urban and Schwarzenberg
1 Edition 1947
2 Edition 1949
3 Edition 1951
4 Edition 1953
5 Edition 1955
6 Edition 1957

VII Schnek Die Technik des ungepolsterten Gipsverbandes Vienna Maudrich
1 German edition 1930
1 English edition 1932
2 German edition 1937

VIII Schnek Rontgendiagnostik der Knochenverletzung Vienna Maudrich 1932

IX Ehalt Behandlung der offenen Bruche der langen Rohrenknochen mit Einschluß der Behandlungsergebnisse Vienna Maudrich
1 German edition 1938
1 Spanish edition 1940

X Kromer Die verletzte Hand Vienna Maudrich
1 German edition 1938
1 Spanish edition 1941
2 German edition 1945

XI Kromer Der verletzte Meniscus Vienna Maudrich
1 Edition 1942
2 Edition 1944
3 Edition 1956

XII Wittmoser Die Reverdinplastik Vienna Maudrich 1946

XIII Slany Stumpfe Bauchverletzungen Vienna Maudrich 1948

XIV Mayr Praxis der Begutachtung Vienna Maudrich 1954

XV Schutz Das arztliche Gutachten im Privatversicherungswesen Vienna Maudrich 1956

XVI Ender Krotscheck and Simon Weidner Chirurgie der Handverletzungen Vienna Springer 1957

Scientific Publications From the Accident Hospitals

Accident Hospital, Vienna, 1926—1957, 742 publications and 22 teaching films

Accident Hospital, Graz, 1940—1957, 235 publications and 17 teaching films

Accident Hospital, Linz, 1951—1957, 102 publications and 24 teaching films

Three books were published from the Accident Hospital Graz

Books I Ehalt Unfallpraxis Berlin de Gruyter
1 Edition 1943
2 Edition 1948
3 Edition 1951
4 Edition 1954

II Ehalt Unfallchirurgie im Rontgenbild Vienna Maudrich
1 German edition 1950
1 Spanish edition 1951
2 German edition 1952

III Russe Atlas Unfallchirurgischer Operationen Vienna Maudrich 1955 with German English and French text

One book appeared from the Accident Hospital, Linz

IV Jorg Bohler German translation of Sterling Bunnell Surgery of the Hand Vienna Maudrich 1957

XI SPECIALITY FOR ACCIDENT SURGERY

In 1951, in spite of much vigorous opposition, a separate specialty was established for accident surgery According to the Bundesgesetzblatt of March 31, 1951, No 64, the following training of six years is required three years accident surgery, of which 2 years must be as an assistant, 2½ years general surgery and ½ year of orthopedics Since as a rule it is not possible to become assistant before three to four years, the training can seldom be completed in less than eight years Thus the independent accident stations and the Accident Hospitals are assured of obtaining well-trained doctors as directors

XII THE RELATION OF SURGEONS TO ACCIDENT SURGEONS

Often the concern is expressed that dissentions could arise between the two In most hospitals with independent accident stations the surgeons are now happy that they are relieved of the time consuming work with accidents and the paper work for the accident insurance companies and the responsibilities connected with these two, and that they can devote themselves more to their other responsibilities Most surgeons admit that the previous system in which every 1—2 years a different assistant surgeon has been given the responsibility of the treatment of the accidents has not proved satisfactory

XIII THE INFLUENCE OF THE VIENNA ACCIDENT HOSPITAL ON THE DEVELOPMENT OF ACCIDENT SURGERY IN FOREIGN COUNTRIES

Even before the opening of the Accident Hospital of Vienna, the Deutsche orthopadische Gesellschaft[1] on December 30, 1919, in a communication to the German Reich government wrote among other things "The functional treatment of accidents as carried out on war injuries by Dr Bohler in exemplary manner with brilliant results, shows what sums of money can be saved for the state and the economy

In 1927 I was invited by the Workers Accident Insurance Company in Brunn (Brno) to give a lecture at the university about the experiences in the Vienna Accident Hospital Immediately thereafter the administration there decided to found an accident hospital also in Brunn adjacent the Company building This was opened in 1930 under the direction of Professor Nowak who is still its director He was trained in the Accident Hospital of Vienna for a considerable time Similar plans in Prague and Preßburg could not be carried out because of the war

In 1930 I was invited to Stockholm and Brussels and later to North America to lecture

In 1932 I was invited to Oslo

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[1] Zeitschr orthop Chir 39 13 1920

In 1932, in the third edition of my book *The Treatment of Fractures*, in the Appendix under the title "Fractures and Accident Surgery and their Relation to the Environment," I set up a plan for *instruction* in accident surgery and for *organization* of treatment in independent accident stations and separate accident hospitals, which was wide in scope I summarized my works published since 1917 on these subjects

In 1932 the first German edition of my book was translated into Russian and in 1937 the third also, namely 10,000 copies Professor Priorow who wrote the introduction is now director of the Accident Surgical and Orthopedic University Clinic in Moscow with 400 beds Currently 36 professors, who dedicate themselves to research, are employed there All together there are said to be 83 Accident Hospitals in Russia

In 1933 Colonel Sokolowski, Surgeon-in Chief of the Polish army, translated my book into Polish In addition he had the Appendix, 'Fractures and Accident Surgery and Their Relation to the Environment, reprinted and distributed to the accident insurance carriers Thereupon the Worker's Accident Insurance Companies of Poland and the National Health Insurance built an Accident Hospital in Warsaw near the University Clinics, so that the students also had the opportunity to learn there He staffed the hospital with military doctors In this way they had the opportunity already in peacetime to learn accident surgery thoroughly from large material This is most important for a wartime surgeon

In 1933 Professor Tancredi, Oberarzt of the orthopedic clinic in Rome began the Italian translation of my book Professor Dalla Vedova, the director of the orthopedic clinic wrote the introduction Thereupon in 1936 he opened the new clinic for Accident Surgery and Orthopedics in the university city of Rome The further translations of my books into Italian were carried out through Professor Pachner, Director of the independent accident station at the University of Genoa and Dr Carnera from the independent accident station in Meran

Almost every year the Accident Insurance Company of Italy (INAIL) sends six doctors to the Vienna Accident Hospital for training

In 1934 Professor Jimeno Vidal translated my book into Spanish and then founded an Accident Station at the Surgical University Clinic in Barcelona

In 1937 I received an invitation to Spain There I had the opportunity to visit various military hospitals In most of these I met surgeons that had spent more or less time at the Accident Hospital in Vienna During the war both sides worked according to the Spanish translation of my book All field hospitals of both political parties were uniformly equipped with the apparatus listed there (see Vol I/figs 293—295) The results were surprisingly good While the mortality in the first world war, for instance in fractures of the femur, averaged 50%, according to the reports of Jimeno Vidal and Arguelles, in Spain it fell to 5—6%

In 1952 in Madrid the University Clinic for accident surgery and industrial diseases was opened under the direction of Professor de la Fuente This clinic was built by the Spanish Workers Accident Insurance Company in the university city in full recognition of the *importance of training*

In 1953 I was invited by the Spanish Workers Insurance Company to give lectures in Madrid, Granada, Valencia and Barcelona

Accident surgery has experienced a particularly great impetus in the last 20 years in Middle and South America

In 1937 the Caja de Accidentes del Trabajo (Workers Accident Insurance Company) in Santiago, Chile built a University Accident Surgery Clinic with 200 beds It is under the direction of Professor Theodoro Gebauer, who in 1930 and in 1950 was at the Accident Hospital in Vienna The Workers Accident Insurance Company in Chile was founded by the ministerial advisor Dr Mumelter, the former representative of the board of supervisors at the Workers Insurance Company in Vienna

In 1941 a University Accident Surgery Clinic with 120 beds under the direction of Professor Bado was built next to the large clinic building of the university by the Banco de Seguros del Estado (Workers Insurance Company) of Uruguay in Montevideo

In 1942 a University Accident Surgery and Orthopedic Clinic with 120 beds was built on the university clinic grounds in Sao Paolo, Brazil Since in a short time it was too small, a new clinic with 280 beds was built which was opened in 1953 This clinic is under the direction of Professor Godoy Moreiro, who had my book *Verbandlehre* translated into Portuguese

In 1944 the Instituto Mexicano del Seguro Social (Workers Accident Insurance Company) built a University Clinic for Accident Surgery in Mexico City with 200 beds under the direction of Professor Farrill At the same time the Insurance Company of the Railroads built a hospital with a large department for accident surgery under the direction of Professor Velasco Zimbron

In Argentina numerous accident stations have been established under the direction of Professor Lelio Zeno who translated the first edition of my book into Spanish

In 1953 I with Primarius Dr Jorg Bohler was invited to give lectures in Mexico, Havana (Cuba), Caracas (Vanezuela), Lima (Peru), Santiago (Chile), Buenos Aires (Argentina), Sao Paolo and Rio de Janeiro (Brazil), and Lisbon (Portugal)

In 1934 Professor Hey Groves translated my book into English In addition he wrote about the organization of the Vienna Accident Hospital in numerous articles

In 1936, under the stimulus from Hey Groves, a delegation from the English Ministry of Education, the Ministry of Health and the Ministry of War visited the Accident Hospital The Ministry of Health thereupon ordered that separate Accident Departments be set up in many hospitals At that time Birmingham reveiced a model Accident Hospital with 250 beds under the direction of Gissane The interest shown in England can be seen from the guest list on page 2290, which shows, that the number of English surgeons visiting the Accident Hospital increased in 1937 to 99

During the second world war the English army was equipped with apparatus designed by me

The Russian and Italian armies used my frame for femoral fractures

In 1949 my book *Verbandlehre* was translated into Chinese According to a report the soldiers of the Chinese Medical Corps could not be promoted to noncommissioned officers until they had passed an examination based on this book

Currently the large three volume work is also being translated into Chinese

In 1950 Dr Ahrer was called to Athens from the Vienna Accident Hospital in order to establish and direct a department of reconstructive surgery

In 1955 building of an accident hospital with 250 beds was begun in Athens

In 1952 the Accident Insurance of Portugal conceived the plan to build an accident hospital of its own It requested the Vienna Accident Hospital for plans for its building and organization Lisbon currently has two well equipped, independent accident units

In 1951 we accepted invitations to lecture from the University of Boston, New York and Washington and in 1955 accepted invitations from Philadelphia and San Francisco

In 1956 on invitation from the Universities of Teheran and Shiras we conducted guest lectures in Persia

XIV PROGRAM FOR THE FUTURE

Because of the economic importance of Accident Surgery (see pp 2175 to 2193) an *independent clinic for accident surgery will be established in every university in the world* in the not too distant future Accident surgery will become a separate important subject The students will be instructed in shock treatment, immobilization and *painless* exercise therapy in such a manner that they will be able to treat many accidents themselves with good results

In hospitals with more than 100 surgical beds independent accident units with their own beds, separate operating rooms, separate X-ray departments and separate rooms for after treatment and disability evaluation will be established (see p 2215)

In the smaller hospitals of the rural areas only surgeons will be employed who have had at least one year of training in an accident clinic or an accident hospital or specialists in accident surgery will be employed

In the larger cities and large industrial centers accident hospitals will arise As soon as this program is carried out the currently still common avoidable unfavorable results attributable to treatment described on pages 2162—2169 and presented in figures 3055—3060 will become rarities

How the financial can be obtained for erection of independent accident units, accident hospitals and university clinics for accident surgery and disability evaluation through reduction of the treatment time and especially through savings in disability payments is shown on pages 2188, 2190 and in figures 3087 to 3090

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